

KEVIN HANDRECK

Gardening Down-Under

A guide to healthier soils and plants



SECOND EDITION

VISIT...

LANZAROTE
Caliente.COM

Gardening **Down-Under**

This page intentionally left blank

KEVIN HANDRECK

Gardening Down-Under

A guide to healthier soils and plants

SECOND EDITION



CSIRO
PUBLISHING

© CSIRO 2001

First Published 2001

Reprinted 2002, 2009

All rights reserved. Except under the conditions described in the Australian *Copyright Act 1968* and subsequent amendments, no part of this publication may be reproduced, stored in a retrieval system or transmitted in any form or by any means, electronic, mechanical, photocopying, recording, duplicating or otherwise, without the prior permission of the copyright owner. Contact **CSIRO PUBLISHING** for all permission requests.

National Library of Australia Cataloguing-in-Publication entry

Handreck, Kevin, 1938– .

Gardening down-under : a guide to healthier soils and plants.

2nd ed.

Includes index.

ISBN 0 643 06677 2.

1. Gardening – Australia – Handbooks, manuals, etc. 2. Gardening – New Zealand – Handbooks, manuals, etc. 3. Plants – Nutrition. 4. Soils. 5. Potting soils. 6. Plant growing media. I. CSIRO. II. Title.

635.04891

Published by and available from:

CSIRO PUBLISHING
150 Oxford Street (PO Box 1139)
Collingwood VIC 3066
Australia

Telephone: +61 3 9662 7500
Fax: +61 3 9662 7555
Email: sales@publish.csiro.au
Web site: www.publish.csiro.au

All photographs © Kevin Handreck unless otherwise credited.

Cover: Photograph of author by Robert Kerton

Set in 10.5pt/13.5pt Minion

Cover and text design by James Kelly

Printed in Australia by GEON Impact Printing



Foreword

Gardens are built on soils. Soils are for plants. Plants improve soils. Soils and plants, plants and soils — they are inseparable in our gardens. What happens ‘down-under’ controls what plants do. An infertile soil produces plants of inferior quality. Vigorous, healthy plant growth is possible only on soils that can provide all the essentials for plant growth.

This book is about soils, but it is also about those other growing media – potting mixes – in which many of us grow plants. Soils and potting mixes are different in many ways, but they are also similar in that they must both provide the same essentials for plant growth. They must provide water, nutrients and oxygen; they must both be of the right temperature, be free from toxins and have no more than low numbers of disease-causing organisms.

This second edition of *Gardening Down-Under* contains all the information in the first edition and more. Where necessary, the information has been updated.

Gardening Down-Under provides sound information about soils and potting mixes. It shows why these media are the way they are, how they ‘work’ and how you can manage and improve them. It also provides detailed information about fertilisers of all types.

The book also contains many quick ‘recipes’ for such activities as making compost, overcoming water repellency, applying water and fertiliser, and altering pH. But the book also has sections that give answers to many ‘why’ questions about soils, potting mixes and fertilisers.

By delving into the various parts of this book you will increase your understanding of what happens in soils and potting mixes. I hope that as your understanding of what happens ‘down-under’ increases, your success with and enjoyment of growing plants will also increase.

Kevin Handreck, BSc, MAgrSc, FAIH

March 2001

This page intentionally left blank



Contents

1 GREEN PLANTS	1	4 DEALING WITH DEAD PLANTS	73
Plant Tops	2	Recycling is Natural	73
Photosynthesis	2	Recycling via Mulch	74
Plant Roots	4	Recycling via Burying	76
Mycorrhizal Fungi	7	Recycling via Composting	77
Effects of Temperature on Plants	8	The Not-So-Secret Life of a Compost Heap	87
Plants Affect One Another	10	Buying Commercially Made Compost	92
2 SOILS	11	Recycling via Vermicomposting	92
What on Earth is Soil?	11	Some Facts About Vermicompost	97
Formation of Soils	12	Conclusion	99
Soil Colour	14	5 ORGANIC MATTER	100
How to Really Understand Your Soil – a Challenge	14	Using Composts and Vermicomposts	100
The Gritty Facts About Soils	17	Using Other Organic Materials	102
Using Information about Texture	20	Some Facts About Soil Organic Matter and Humus	103
Beyond Grittiness	21	The Good Things About Organic Matter	104
Effects of Earthworms on Soils	27	Possible Problems with Organic Matter	111
Dig or No-Dig?	29	6 UNDERSTANDING FERTILISERS	115
Converting a Building Site into a Garden	34	Definitions	115
Planting Trees and Shrubs	35	Organic and 'Chemical'	115
How to Assess Soil Before You Buy It	38	Background to Plant Nutrients	117
Selecting a Growing Medium for Large Tubs and Planter Beds	39	Reading the Signs	129
How to Reduce the Amount of Root Disease in Your Garden	39	7 USING FERTILISERS	137
3 CHEMISTRY FOR GARDENERS	49	Fertilisers for New Gardens	137
Have You Ever Wondered?	49	Fertilisers for Maintaining Plant Growth	139
Elements and Atoms	50	Making Your Own Organic Liquid Manure	149
Acidity and Alkalinity	54	The Special Needs of Australian Native Plants	150
How to Alter Soil pH	56	Green Manure Crops	151
Measuring Soil pH	58	Answers to Common Questions About Fertilisers	152
Clay and Humus	59		
Clay, Humus and Plant Nutrition	63		
Buffer Capacity	63		

8 WATER	154	11 GROWING PLANTS IN CONTAINERS	215
Getting the Most Out of Rain	154	Starting Off	215
The Soil as a Reservoir	154	Potting-Up and Repotting	215
Getting Water Into Soils	155	Tubs	217
Water in Soils	158	Choosing Pots and Other Containers	217
Transpiration: the Evaporation of Soil Water Through Plants	160	A General Caution	219
Watering	164	Water and Plants in Containers	219
Using Evaporation Figures	170	Avoiding 'Overwatering'	221
Some General Water-Saving Hints	173	Effect of Pot Depth	224
Dealing with Too Much Water	176	Changing the Air-Filled Porosity of a Mix	225
Garden Watering Systems	187	Matching Watering With Mix, Plant and Environment	225
9 GARDENING WITH SALTY WATER	192	Crocking	227
What is Salty Water?	192	Temperature in Pots	227
How Do I Know When My Water Is Salty?	193	Dealing with Non-Wetting Mixes	228
How Salts Damage Plants	193	Australian Standard Potting Mixes	231
Coping with Salty Water	195	Life in Potting Mixes	242
Using Effluent Waters	196	Personal Hygiene	244
Lists of Plants with Different Tolerances to Salts	197	Propagation	245
10 LAWNS	199	12 FERTILISERS FOR PLANTS IN CONTAINERS	247
Choosing the Best Lawn Grass for Your Area	199	Recipes for Using Fertilisers	247
Cultivars and Comments	200	Soluble Fertilisers	249
Prepare the Soil Properly	202	Controlled (Slow)-Release Fertilisers	253
When to Sow or Plant	203	How Much Fertiliser, and How Often to Apply?	254
Early Care of New Lawns	206	Nitrogen Drawdown in Potting Mixes	255
A Few Hints on Watering Lawns	206	Information for Those Who Want More Understanding of Fertilisers	256
Mowing	208	Avoiding and Overcoming Salinity Problems in Containers	260
Topdressing	209	How to Avoid Phosphorus Toxicity	261
Dealing with Thatch	209	Potting Mixes and Fertilisers for Organic Gardeners	261
Correcting pH	210	13 GARDENING IN CONTAINERS: SOME PRACTICALITIES	264
Compaction	210	Potting Mix pH	264
Fertilising Lawns	210	Measuring the Air-Filled Porosity of a Potting Mix	269
Lawns for Organic Gardeners	214	Wettability of a Potting Mix	272
		Making Your Own Mix	281
		INDEX	285



1 Green plants

The world of green plants is one of almost infinite variety. Just think of the many different flowering plants that you can grow in your garden, the wide range of fruit and vegetables that you can buy at the greengrocer, the many thousands of different trees and shrubs from which you can choose at your local garden centre, or the richness of a tropical rainforest.

Yet within this diversity run some common threads.

- (Almost) every plant has a top and a bottom.
- The top is green, and in many plants it has leaves, stems, flowers and fruits.
- The bottom part – the roots – is usually hidden away in soil or some other growing medium, such as the organic litter in the cleft of a tree.
- Both tops and roots are essential. The decapitated roots of many plants (but not of Wisteria and poplar!) soon die; tops alone either grow new roots or they die.
- All plants have some means of reproducing themselves, either through spores (ferns) or seeds (other plants).
- Roots take water and nutrients for the whole plant from the soil around them.

Before we delve into what goes on between plants and soils, let's have a quick look at each of the parts of plants.

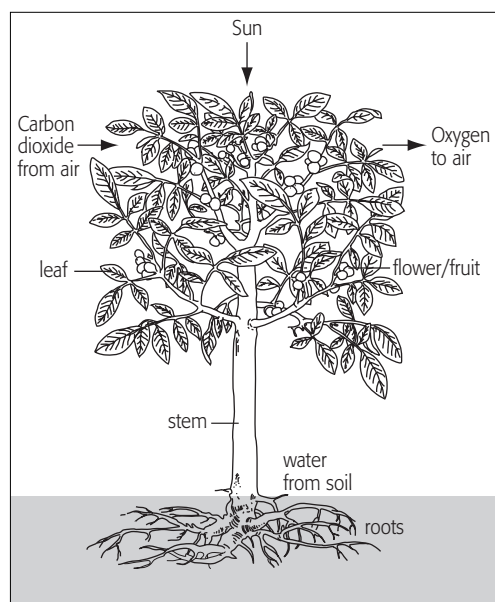
PLANT TOPS

Stem, leaf, flower, fruit: these are the names we use for the main parts of plant tops that we see every day.

Stems (including trunks and branches) are mainly for holding the leaves up to the light. Some specialised stems (e.g. bulbs, corms) store food; some (e.g. in cacti) store water; others (rhizomes and stolons) store food, but also produce new plants as they grow through the soil or over its surface.

Leaves are held up towards sunlight so that they can use its energy to make sugars from water and the carbon dioxide of the air. These sugars are the basic building blocks from which the whole plant is made.

Flowers and seed are for the future: they ensure the survival of the particular type of plant. (In ferns, flower and seed are replaced by spores and prothallia.)



The main parts of a typical plant.

PHOTOSYNTHESIS

Photosynthesis is the process by which green plants use the energy of sunlight to produce sugars and other carbohydrates from water and carbon dioxide. Greenness is essential, because it is green-coloured chlorophyll that captures the energy. Also essential are 12(+) nutrient elements (pp. 119, 129).

Water and nutrients arrive in leaves from the soil through roots and stems. Carbon dioxide arrives through small holes or pores (stomata) in the outer surfaces of leaves. The carbon dioxide diffuses through stomata in much the same way as an odour moves from one room to another.

Inside the stomata, some of the carbon dioxide passes through cell walls into the cells of the plant. Eventually it ends up in the chloroplasts – the small bodies inside leaves that contain the chlorophyll. There, complex reactions, driven by sunlight and supervised by nutrient elements, join carbon dioxide and water together to form sugars and other simple organic chemicals.

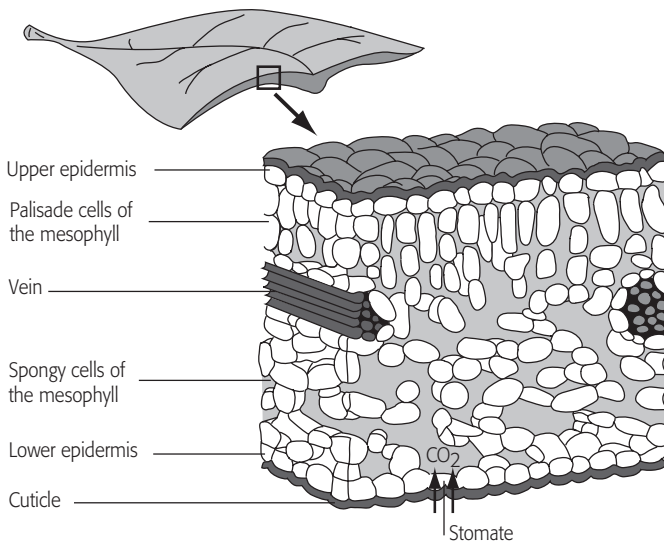
Sugars are the basic building blocks for the many other, often complex, compounds of which plants are made. These compounds include cellulose, lignin, proteins, vitamins, hormones and enzymes. The sugars are moved throughout the plant, especially to shoot and root tips, where growth is fastest.

Plant growth rate increases as the carbon dioxide content of the air increases. Nurseries often enrich the air inside their greenhouses from the 0.035% carbon dioxide in the air to around 0.1–0.15%. The increasing concentration of carbon dioxide in the atmosphere, caused by the burning of fossil fuels, will increase the rate of growth of well-fertilised, well-watered plants.

LIGHT

Light has two major effects on plants. It provides the energy for photosynthesis. In many plants, it also controls the time of flowering. Flower buds do not start to form in many plants until the length of the dark part of the day is long or short enough for this to happen. For example, chrysanthemums will set buds and flower in time for Mothers' Day in southern Australia only if they are surrounded by blackout screens that give them nights of 12 hours or longer.

The intensity of sunlight that different plants require for good growth, or can tolerate, varies enormously. At one extreme are desert plants that need



Typical arrangement of cells in a leaf, showing the presence of a stoma.

prolonged very bright light. At the other extreme are our 'indoor plants' that have come from the very dark understoreys of dense tropical rainforests.

Our success in growing a particular plant depends on us giving it the amount of light that it requires. For example, roses will not flower or will flower poorly if they are grown in shade. A *Maranta* (Prayer Plant) will look pale and 'washed-out' if it is grown in bright light.

Two weeks in a very dark place indoors is about the limit for even the most tolerant of shade-loving plants. Rotating them with plants that are kept in brighter light will prevent deterioration in quality.

PLANT ROOTS

'Out of sight' should not be 'out of mind' as far as plant roots are concerned. Of course they are not as pretty as leaves and flowers, but a little study soon shows them to be equally fascinating.

Have a close look at the roots of the next weeds that you remove from your garden. Dig carefully and gently wash the soil from the roots. Note that some weeds have a strong, thick taproot from which thinner roots radiate into the soil. Others have a multitude of fine roots growing from the base of the aboveground parts.

Try to measure the total length of all of the roots of one plant. You will probably give up long before you get to the 630 kilometres of roots once found on a large rye plant!

Roots are long because they have to anchor the plant in the soil: they have to hold it down against strong winds and grazing animals. Their extensive network collects water and mineral nutrients from the soil. The roots of some plants (e.g. carrot) store excess food for the future needs of the plant.

Most of the roots of typical garden plants are in the top 30–50 centimetres of soil. Cacti have shallow root systems so that they can gain most benefit from the occasional rains falling in their desert habitats. Some



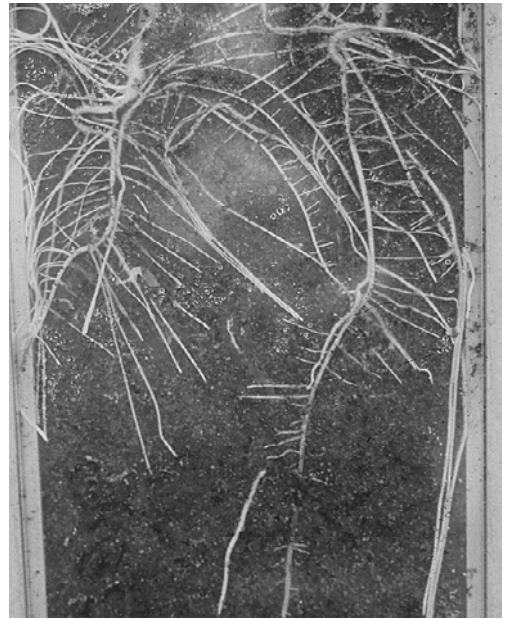
The roots of epiphytic orchids grow easily in warm, humid air.

Australian native plants have taproots that can penetrate to 30 metres and more. The roots of most trees extend horizontally well beyond the ends of their branches. Often, about 60% of the total root system of large trees is outside the 'drip circle'.

Roots that grow deep into the soil recycle back to surface soil, nutrients that have leached from the surface in drainage waters. An ecologically balanced garden will have at least some deep-rooted plants.

Here are a few examples of the effects of gardening practices on plant roots.

- The density of roots increases in localised areas of application of modest amounts of fertiliser. Excessively large applications of nitrogenous fertiliser give extra shoot growth, but decreased root growth.
- Light to moderate pruning during the growing season reduces root growth for several months. One consequence of this is that young non-dormant trees should not be pruned at transplanting, as this is a time when as much root growth as possible is desirable.
- Digging under and near shrubs and trees damages their roots and will reduce their rate of growth. Never disturb the soil under shallow-rooted trees such as avocados and citrus.



These bean seedlings took just two weeks to produce an extensive root system.



Most of the roots of garden plants are in the top thirty or so centimetres of soil.

A CLOSER LOOK AT ROOTS

Plants get most of their water and essential nutrient elements from the soil by absorption through the roots. For those who like to know a little about the 'how' of things, here is some information about this absorption.

ABSORPTION OF WATER

Much of the water is absorbed in the root-hair zone just a little back from the growing tip of the root, but some is absorbed through older parts of the root system. Root hairs are elongated cells sticking out into the soil from the surface of the root. They greatly enlarge the area of root surface that is in close contact with the soil.

Most of the water that enters roots does so because it is more-or-less sucked in under the influence of water that is lost by evaporation from the leaves, in much the same way as liquid rises through a drinking straw under the influence of the suction of our mouth and lungs.

At the same time, some enters by the process of osmosis. The liquid (sap) inside a root is usually 'thicker' than the water in soil, that is, it has more chemicals dissolved in it, and this aids the uptake of water by the plant.

But if we apply too much soluble fertiliser to a soil, we can easily stop or even reverse the flow of water. The plant's top wilts and the leaves may burn. The plant will die unless the salts are diluted in extra water.



Palms have a good hold on the ground.

ABSORPTION OF NUTRIENTS

Plant roots take up nutrient elements by absorbing them from the water in the soil (the soil solution). The actively growing cells near root tips and in the root-hair zone select the nutrients needed by the plant. They expend energy and use oxygen in bringing the nutrients into the plant.

All this is quite easy if there is plenty of each of the nutrients in the soil solution. But sometimes the concentration of one or more nutrients is too low to satisfy the needs of the plant. Faced with a shortage, many plants are able to modify the soil immediately around their roots (called the rhizosphere). They exude various chemicals that are able to dissolve nutrients from soil minerals.

For example, the roots of plants such as chrysanthemums and lupins are able to exude acid and chelating compounds into their rhizosphere as a response to a shortage of iron. Plants that are not able to do this (e.g. rhododendrons, camellias) may show symptoms of iron deficiency (yellowing of the youngest leaves) when they are grown in the same soil.

SELF-HELP

Something over half of all of the organic matter produced during photosynthesis ends up as root exudates and dead pieces of roots in the growing medium. That can be as much as 2 kg of (dry) organic matter going into each square metre of soil each year. This sounds wasteful, but it is really enlightened self-help. This organic matter provides a rich diet for countless millions of micro-organisms. Amongst these organisms are some that protect the roots against pathogens and some that help root growth through the hormones that they produce.

When next you look at some plant roots, think of the thriving cauldron of life that surrounds them, and marvel at the richness of life.

MYCORRHIZAL FUNGI

If you go down to the woods (pine forest) one day you may be lucky enough to see some 'toadstools' growing under the trees (p. 41). Toadstools and mushrooms are the fruit of fungi. In a pine forest the 'toadstools' are likely to be from mycorrhizal fungi that live with the roots of the pine trees.

Spores of these fungi invade young roots, but instead of spreading and killing the tree they start to live in harmony with the host tree. The tree supplies the fungus with sugars; the fungus, through the huge network of hyphae (threadlike attachments that act like roots) that it sends out through the soil (p. 41), brings back nutrient elements such as phosphorus and zinc. The fungus gives the tree what amounts to an enormously larger root system.

Mycorrhizal fungi also increase the tolerance of plants to drought, high temperatures, some pathogens and some herbicides.

Most plants form liaisons with mycorrhizal fungi. The small proportion that don't include the brassicas (cabbage, cauliflower, turnips, mustard, etc.), wallflower, candy tuft, stocks, horse radish and the saltbushes.

SOME PRACTICAL INFORMATION ABOUT MYCORRHIZAL FUNGI

- Mycorrhizal fungi are killed by soil fumigants such as methyl bromide and Metham.
- The systemic fungicides Benlate and Basamid reduce the numbers of mycorrhizas formed.
- They are killed if soil or potting mix is heated at 60°C for 30 minutes.
- Mycorrhizas are not formed on plants growing in soils with high levels of soluble phosphorus.
- The normal levels of phosphorus in potting mixes generally prevent formation of mycorrhizas.
- Mycorrhizal fungi need oxygen, so their effectiveness is reduced under waterlogged conditions.
- Orchid seeds will germinate only when they are in contact with special types of mycorrhizal fungi.

EFFECTS OF TEMPERATURE ON PLANTS

Temperature affects plants in many different ways. The main effects of temperature are on rate of growth and ability to produce fruit.

- Plants from the lowland tropics (many of our indoor plants) do not grow at temperatures below 15–17°C, no matter how much they are fed. Their optimum growing temperature is often 25–30°C, and many do not like night temperatures below 20°C. The growth of these plants is slowed if they are irrigated with cold (10–15°C) water. On the other hand, many do not tolerate temperatures higher than about 34°C.
- Plants from high elevations in the tropics prefer temperatures that are about 5°C lower than those given above for lowland tropical plants. These plants – fuchsias are a good example – stop growing if the temperature of the soil or potting mix around their roots rises above about 25°C. In hot climates they should be grown in containers that allow evaporative cooling of the potting mix (earthenware pots or fibre-lined baskets) rather than in plastic pots.

Both groups of tropical plants prefer even temperatures throughout the year.

- Many plants from temperate climates grow slowly at 8°C, with maximum growth in the air temperature range 20–30°C, and root temperatures of



These *Begonia dregei* plants collapsed and died because of excessive heating of their roots during a heatwave.

20–25°C. Root growth ceases at a soil temperature of about 5°C. These plants tend to prefer climates in which night temperatures are considerably lower than day temperatures.

- Plants from regions where winters are severe go dormant in winter. Many of them (including cherries and other stone fruits) will not fruit properly or at all if they do not get sufficient winter chill. There are now varieties of these trees available that have lowered need for chilling before they set fruit.
- Many plants that grow from bulbs need special sequences of temperature if they are to flower properly, or at all. For example, Amazon lilies need several weeks of temperatures around 29°C, followed by a drop to 21°C, if flowering is to be certain.
- Plants from hot areas often grow best at temperatures in the mid 30s. A widely grown example is couch grass, which is slow to start growth in spring in cool areas, but thrives in 40°C heat.

When one of your plants is not growing as well as you think it should, consider unfavourable temperature as a possible cause, rather than lack of nutrients, disease, faulty watering or poor soil structure.

PLANTS AFFECT ONE ANOTHER

Readers may have come across statements in books to the effect that some plants benefit from the presence nearby of certain other plants. These other plants are often referred to as companion plants. On the other hand, some plants are said to be harmed by other plants. There is some truth in these statements, but perhaps not as much as some books suggest.

A plant can be affected by others in many ways:

- Shading by another plant will reduce the growth of plants that need full sun.
- On the other hand, shading will allow shade-loving plants to survive and thrive.
- Plants that send their roots deep into the soil can bring from the subsoil nutrients that will later, via litterfall, help feed shallow-rooted plants.
- Plants with aggressive root systems (e.g. ash trees) rob nutrients and water from other plants.
- Chemicals, including nutrients and plant growth hormones, are washed by rain and sprinkler water from the leaves of plants. The amounts washed out are greater from old (flowering) plants than from young plants. These chemicals can increase or decrease the growth of other plants onto which they fall.
- Chemicals exuded from the roots of some plants can stimulate or reduce the growth of other plants whose roots are nearby.
- Chemicals exuded from stressed roots can encourage attack by disease-causing organisms.
- On the other hand, some chemicals exuded by roots can stimulate the activity of micro-organisms that help protect roots from attack.
- Chemicals produced during decomposition in the soil of old roots of peaches and apples severely retard the growth of young trees of this same group planted into the soil.
- Ripening fruit gives off ethylene gas, which can cause flowers to drop from nearby plants in confined spaces.
- Some plants produce chemicals that repel insects from themselves and perhaps also from other nearby plants.
- Birds attracted to some plants may reduce insect populations around them.



2 Soils

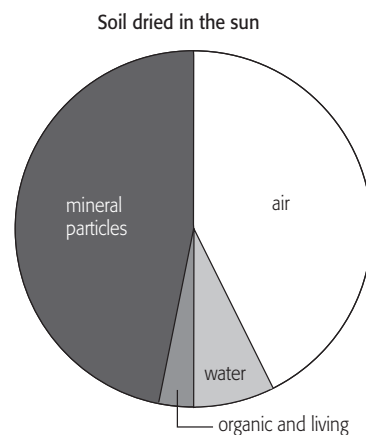
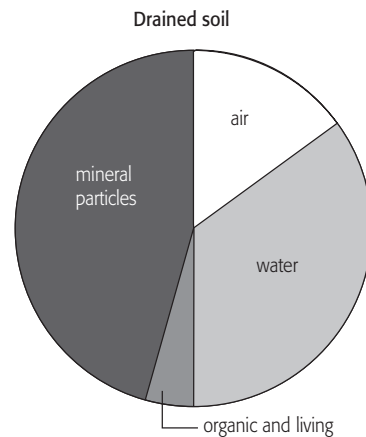
WHAT ON EARTH IS SOIL?

One answer to this question is that soil is the thin coating of materials that covers the earth's rocks.

Another answer is that it is all that there is between us and starvation.

Yet another is that there is not one soil but many thousands of soil types, each with its own peculiarities. But each of these soils has five main components, as follows.

- Mineral particles (the inorganic fraction) – containing small particles of rock and other minerals that have been produced from these rocks by weathering.
- Organic materials – humus and the dead and decaying parts of plants and soil animals.
- Water – the 'soil solution', in which nutrient elements for plants are dissolved.
- Air – which fills the spaces between soil particles not filled by soil solution.
- Living organisms – ranging in size from small animals to viruses.



Soils have different proportions of their main components. **Top:** Drained soil. **Bottom:** Soil dried in the sun.

If every soil has the same types of components, why is it that soils of different areas can be so very different from one another? Soils look and behave differently from one another because:

- They have different proportions of the main components;
- These components are grouped together in different ways;
- There are many different types of minerals in the inorganic fraction, and each soil has different proportions of them;
- The inorganic fractions of different soils contain widely different proportions of large and small particles.
- They have been formed with the aid of quite different types of plants.

This is not a textbook, so only a little more information is given.



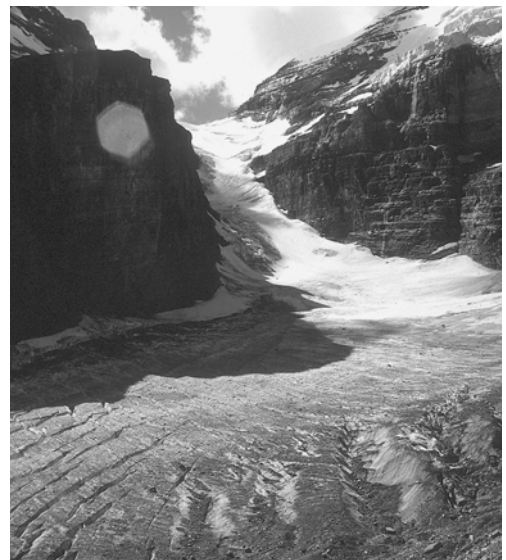
Our soils are in our hands – to preserve and improve for future generations.

FORMATION OF SOILS

The soil that sticks to your shoes when you garden has a very, very long history. In Australia that history often stretches back for many hundreds of thousands of years.

Soils have been formed from rocks and sediments by the combined influence of water, air, heat (and cold), micro-organisms, plants, animals and time. The processes involved are usually referred to as ‘weathering’.

Physical weathering processes include the breaking up of rocks by ice and extreme heat, blasting by wind-driven sand, rasping by glaciers and grinding by water-borne sand and rocks.



Like all glaciers, Bear Glacier in the Canadian Rockies is steadily grinding away the rocks beneath it.

Chemical weathering requires water and oxygen. Water running over rocks or percolating through soils dissolves tiny amounts of the minerals it contacts. The dissolved parts often combine together to form other minerals. Chemical weathering is most rapid in the uppermost layers of a soil as these are generally warmer and contain more oxygen than lower layers.

Living organisms speed up chemical weathering and change the types of products formed.

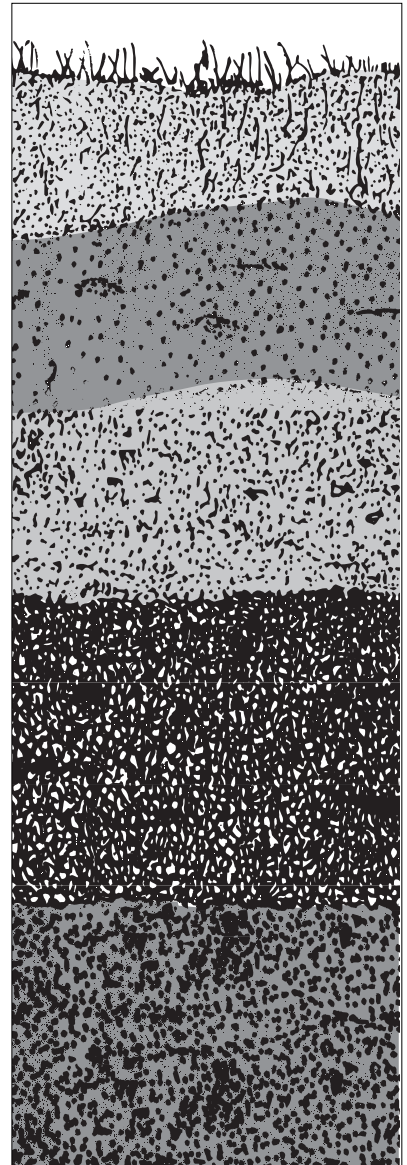
One way of understanding the complexity of weathering processes and the vast variety of different soils formed is to group the processes under four headings as follows:

Additions – e.g. organic matter, which accumulates on the surface of the soil; silt on floodplains during floods.

- Removals – e.g. soluble salts and carbonates leached to lower parts of the soil; nitrogen and sulphur when vegetation is burnt.
- Transfers – e.g. of plant nutrients from lower horizons to the surface, through plants and their litter, or of soil material through the actions of animals such as earthworms and termites.
- Transformations – e.g. weathering of primary minerals such as feldspar and biotite to clay minerals; decomposition of organic residues, with the formation of humus.

All of these changes are still operating in all soils but the balance among them varies from soil to soil, depending on the minerals in the parent material, living organisms, topography and, especially, climate.

Three examples will show how changes in the balance amongst these additions, removals, transfers and transformations produce different soils.



The uppermost layer of a soil is called 'topsoil'. Under topsoil, the lower part of the soil – the subsoil – can often be seen to have layers (horizons) that are differently coloured or have different textures or structure. The whole sequence of horizons is known as the soil profile. Examples of soil profiles can be seen in road and railway cuttings, excavation sites or when we dig holes for plants.

Desert loams, such as those of the region where the state borders of South Australia, Queensland and New South Wales meet, are wet only infrequently and even then they may not be wet to any great depth. Salts and carbonates tend to remain close to the surface and so these soils tend to have a neutral to alkaline pH. There are only small additions of organic matter to the surface soil and limited transformation of minerals.

In contrast, many of the soils of the wetter coastal regions have had salts and carbonates removed from them by water. This has made their surface layers fairly acid. There has been more accumulation of organic matter at the surface and the formation of different types of clay minerals.

Page 42 shows a Queensland Yellow Earth soil.

SOIL COLOUR

The colour of a soil tells us about how well drained it is and its humus content. Yellow, orange, brown and red colours come mainly from different kinds of iron oxides. Most soils contain mixtures of these oxides, with varying proportions giving the wide range of colours found. The sequence from well aerated and drained to frequently waterlogged is red brown, yellow mottled, yellow, grey, green-grey, black. Crops such as citrus, bananas and avocados that do not like 'wet feet' do not thrive on mottled soils.

Soils that are light-coloured or greyish in appearance have often been heavily leached.

Humus (highly decomposed organic matter) darkens any soil, so topsoils are usually darker-coloured than subsoils.

HOW TO REALLY UNDERSTAND YOUR SOIL – A CHALLENGE

If we really want to understand something, we usually find that it is better to look at it, feel it and work with it, rather than to just read about it. Teachers can insist that their students do this, and can supervise. By comparison, authors are disadvantaged: all we can do is request an action and hope that our readers will 'behave' and 'cooperate'.



A slice of topsoil ...



... with its distinctive structure.

This author is now going to make some requests which, if you follow them, will greatly increase your ability to understand the soil of your garden. More information is given on the pages indicated

- Go into your garden and dig up a 5 cm thick block of soil of spade width and about 10 cm deep.

Is there a mulch layer on the surface?

Is the soil moist or dry?

Is the soil easy or hard to dig? (Dry soil is harder to dig than is moist soil. Soils with poor structure (p. 23) are harder to dig than are soils with good structures.)

- Smell the soil. Does it smell 'earthy' or are there other smells coming from the soil, especially the lower part of the block? (Sour smells often indicate poor drainage (p. 185).)
- Put the block of soil on a sheet of newspaper.
- Look closely at its surfaces.

What is its colour, and does the colour vary with depth or from point to point? (For example, black usually indicates a high humus content; multi-colours might mean that the soil is waterlogged in wet weather. See p. 185.) Has the block already fallen apart, or is it still more-or-less in one piece? (Falling apart might mean that the soil is sandy or that it has a loose, friable structure (p. 22).)

Are roots visible in all surfaces?

- Can you see any other layers of soil as you go down the block? (Layers might have been formed naturally, but more often they have been produced during cleaning up after building or by an incompetent landscaper.)

If there are layers, do they look quite dense (compact) or are they loose? (A compact layer could mean that roots are not able to penetrate deep into the soil. Fine soil over a sandy layer will remain saturated after rain.)

Is the whole block just one mass of soil or does its surface have a fine crazing of fractures that divide it up into small crumbs that are still held together? (You are looking at the structure of the soil, which tells you much about how easily water drains through it (p. 22).)

Are there lumps of gravel embedded in the block?

Can you see any large holes in the soil that might have been formed by earthworms chewing their way through it? (Earthworms are really good for soils (p. 27).)

- Gently poke the soil with a knife or piece of stick.

Is it easy or difficult to break apart?

Does the soil look sandy or is it more like a mass of small crumbs, each of which is composed of even smaller particles? (p. 22)

Can you see any soil animals such as earthworms, grubs or beetles?

Does the surface soil behave differently from that below it? (Surface soils (topsoil) with ample amounts of organic matter will be more friable than the subsoil below. But some topsoils form crusts (p. 26).)

- Now take a couple of tablespoons of the soil from the lower part of the block. Place the soil in the palm of one hand and rub some of it between a finger and thumb of the other hand.

Does the volume of the soil decrease



Working moist soil during the determination of its texture.

greatly? A large decrease in volume probably indicates that the soil has a beautiful, well-aggregated structure and excellent drainage (p. 22).

Is the soil gritty or smooth?

Is it easy or difficult to break up the clods and crumbs?

- Moisten the soil in your hand with a little water.

Does the water instantly wet the soil or does it sit on the surface until you start mixing the two? (Water repellence in soils calls for correction by you (p. 113).)

What happens to the colour of the soil? Moist soil always looks darker than dry soil.

- Work the moist soil with fingers and thumb (p. 19).

Does the soil still feel gritty or does it now all feel smooth?

Does it feel sticky and slippery?

If it feels reasonably smooth, can you nevertheless hear grains of fine sand rubbing against one another?

As the soil dries out a little during kneading, does it become very tough to work, or does it just fall apart?

- Now attempt to press it out into a ribbon using finger and thumb. See the table on page 19 for an interpretation of what happens.

Form some of the topsoil into a clod measuring about 5x5x5 mm (if you can).

Drop the clod into a glass of rainwater, distilled or deionised water. (Tap water may be too salty for this test.)

Drop a crumb of the undisturbed soil into another glass of water.

Look closely at what happens to the two pieces of soil over the next 10 minutes. See p. 26 for an interpretation of what happens.

THE GRITTY FACTS ABOUT SOILS

Above the high-water mark of most of Australia's beautiful beaches are *sand* dunes, on which grow grasses, shrubs and low trees.

Every gardener knows that *clay* soils stick to boots and can be very difficult to dig.

Just about every garden book states that a *loam* is the best soil for a garden.

The words ‘sand’, ‘clay’ and ‘loam’ tell us a lot about a soil: they give us a mental picture of what a soil might look like and how it might be expected to behave; they tell us about its texture.

SOIL TEXTURE

In the rag trade, texture is about the surface of woven fabrics. It is about how a fabric appears to the eye and feels to the touch.

Soil scientists have borrowed ‘texture’ from the rag trade. They use the word to describe the way a soil feels when it is kneaded moist in the hand. Soil texture is about how smooth or rough the soil feels. It is therefore about the sizes of the particles of the soil, and the proportions in which they are present.

For example, it is easy to feel the hard grains in a soil that has a sandy texture. It is not

Names and sizes of soil particles

Name	Size range (mm diameter)
Gravel	more than 2
Very coarse sand	1–2
Coarse sand	0.5–1
Medium sand	0.25–0.5
Fine sand	0.1–0.25
Very fine sand	0.05–0.1
Silt	0.002–0.05
Clay and humus	less than 0.002



Clay plus a little water equals mud.



The longer the ribbon, the greater the clay content of the soil.

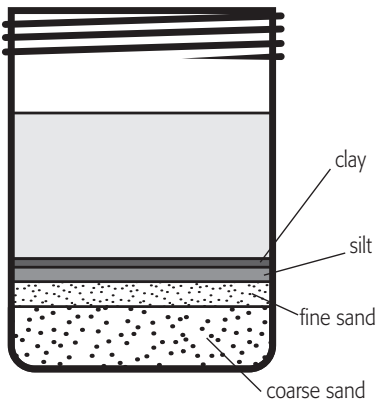
possible to feel the individual particles in a soil of clay texture because they are all very, very small.

Soils with a loam texture have some sand and some smaller particles of silt and clay. The sand grains can be felt when kneading, but the soil is held together by clay and humus amongst the sand.

FINDING THE TEXTURE OF YOUR SOIL

To work out the texture of your soil is a vital step in your making friends with your soil. Here is how to do it. You will also find this simple test useful for checking out soil on offer in soil yards.

- 1. Take a small sample of soil sufficient to fit comfortably in the palm of one hand. Discard any gravel.
- 2. Moisten the soil with water, a little at a time, and knead until there is no apparent change in feel. This will take several minutes.
- 3. Inspect the sample to see if sand is visible; if not, it may still be felt and heard as the sample is worked.



Soil sample shaken up in water and allowed to settle.

Interpretation	
No coherence; cannot be moulded; single grains stick to fingers	Sand
Forms a fragile cast that just bears handling; discolours fingers; ribbon 6 mm	Loamy sand
Forms a cast that just bears handling; individual sand grains can be seen, heard or felt; ribbon 15–25 mm	Sandy loam
Forms a coherent cast that feels spongy but not sandy or silky; may feel greasy if much organic matter is present; ribbon about 25 mm	Loam
Coherent but will crumble; very smooth and silky; ribbon 25 mm	Silty clay loam
Forms a strongly coherent cast in which sand grains can be felt; ribbon 25–40 mm	Sandy clay loam
Forms a coherent cast with a rather spongy feel; plastic when squeezed between thumb and forefinger; smooth to manipulate; ribbon 40–50 mm	Clay loam
Forms a plastic cast, but sand grains can be seen, felt or heard; ribbon 50–75 mm	Sandy clay
Smooth plastic cast that handles like plasticine and can be moulded into rods without fracture; some resistance to ribboning; ribbons 75 mm or more.	Medium to heavy clay

4. Squeeze the sample hard to see whether it will form a ball or cast, and if so, whether the cast is durable or falls apart readily.
5. Finally, squeeze it out between thumb and forefinger with a sliding motion and note the length of self-supporting ribbon that can be formed.

USING INFORMATION ABOUT TEXTURE

Water percolates readily through sands, loamy sands and sandy loams (except those that are water-repellent; see p. 113). Salts are readily leached from these soils, so plants in these soils can be irrigated with water that is too salty for use on heavier (clay) soils. On the other hand fertilisers applied to sands are also readily leached out; compost and other slow-release fertilisers are very useful for supplying nutrients to plants in sandy soils.



The clay-loam on the left holds more water than the sand on the right. Both columns received the same amount of water.

Clay soils, other than those with an excellent structure, are generally difficult to dig as they can be sticky when wet and often set hard on drying. Unless they are deeply cracked, water penetration into many clays is slow; in fact some clays are virtually impervious to water if they are already wet or have been pugged when wet; they make ideal sealing materials for earth-fill dams. Heavy clays are frequently unable to quickly absorb all of the outflow from septic tanks.

Loams are a mixed bag of soils. From a gardener's point of view, the best loams drain freely, yet hold plenty of water for plants. They are easy to dig and give good conditions for root growth. Silty loams often set very hard on drying. Crusts that act like prison walls for seedlings readily form on the surface of some clay loams. As we shall see below, many of these soils can be improved.

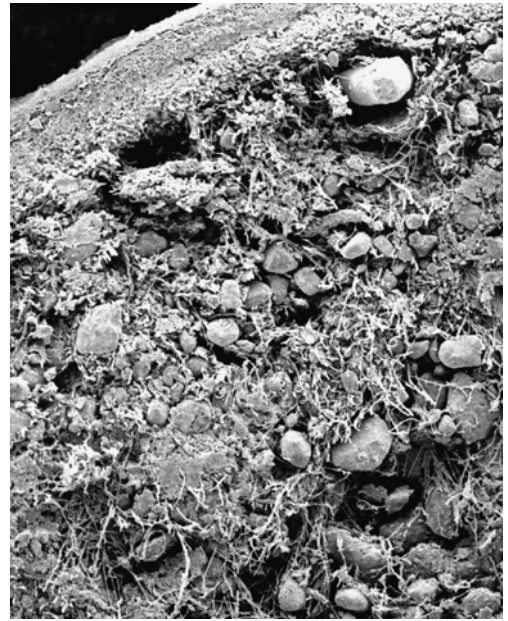
BEYOND GRITTIENESS

Knowing the texture of a soil is useful, but if we are to really understand our soil we must also know about how all those sand, silt, clay and humus particles are bunched together. In other words, we must know something about the structure of a soil if we are really to manage it wisely.

SOIL STRUCTURE

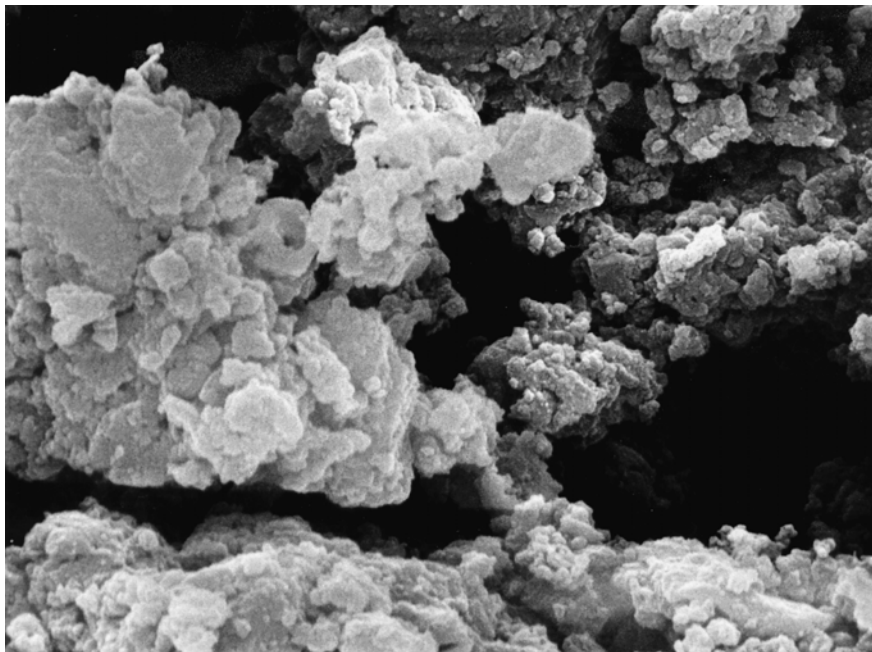
Soil structure is a term used to describe the way the mineral particles and humus of a soil are arranged together. Good structure is essential if plant growth is to be excellent.

Most soils contain large and small particles. Why is it that the small particles don't just fill in the holes between the large ones and so leave the soil like concrete?



Stewart McClure

Crusts on soil surfaces retard infiltration of water and impede plant establishment. Magnification: x 85.



Stewart McClure

The nooks and crannies of a soil, as seen by nematodes. Magnification: x 17 000.

Part of the answer is that soils are 'crumbly'. The mineral particles and humus are grouped together into crumbs, or aggregates. These are then arranged together so that there are spaces, called pores, between them. This arrangement of aggregates gives a soil its characteristic structure.

You probably saw aggregates when you looked at the block of soil that you dug from your garden. The aggregates may have formed a distinctive pattern in the undisturbed soil below spade depth, but in cultivated soil they would most likely have been all jumbled up.

Look at some other patterns of soil structure next time you happen upon a road cutting or an excavation hole.

A soil has good structure if:

- The particles that make up each aggregate are bound together firmly enough so that the aggregates do not break apart when rain falls on them or during normal digging.
- The particles of each aggregate are still held together loosely enough so that small roots can penetrate aggregates to get water and nutrients.
- The aggregates are generally quite small – ideally 0.2 to 3 mm across – rather than larger clods that are quite dense.
- The aggregates are arranged together in such a way that there are many pores (spaces and channels) between them.

Good things about good structure

- Good structure (p. 43) enables plant roots to grow easily through the soil in search of water and nutrients. Plants in such soils use a minimum amount of energy in pushing their roots through the soil and so are able to use most of it for shoot growth.
- Good structure also allows ample supplies of oxygen from the air to percolate down to roots.
- Good structure allows water that falls on the soil to quickly soak in.
- Good structure allows rapid drainage of excess water.

Good structure allows us to have a vegetable garden without the hard work of digging, or if we do dig, the effort needed is reduced compared to that needed with a soil of poor structure.

Poor structure

Soils with poor structure tend to have their particles joined together into dense sheets or large clumps. Such soils may behave in one or more of the following ways:

- They will probably be difficult to dig.
- They may be inclined to remain waterlogged for extended periods during winter or the rainy season.
- Their surfaces may collapse during rain or irrigation, with the collapsed material forming a dense crust. Such a crust will greatly slow the rate at which water can get into the soil.
- They may break into clods which give a very rough seedbed.
- Many of them are easily eroded during rain or strong wind, if they are unprotected by plants.



Years of cultivation have left this soil with a very poor, cloddy structure.

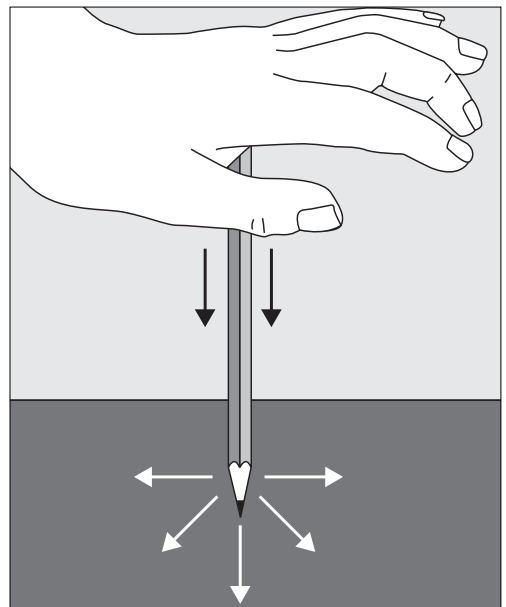
IMPROVING SOIL STRUCTURE

Aggregates are 'glued' together by:

- Organic matter;
- Secretions from living organisms;
- Clay particles;
- A high proportion of calcium ions, relative to magnesium and sodium ions.

Therefore, we should be able to improve the structure of our soil if we:

- Add organic matter. This is so important that a whole chapter is devoted to it (Chapter 5).
- Add clay to sandy soils.
- Supply calcium (p. 27).



Soil compaction is detected by trying to push a pencil into moist soil. The more your palm hurts, the more compact is the soil.

Improving the structure of sandy soils

Sandy soils are excellent for bowling greens and other areas of turf that can be intensively managed and must withstand compaction. Fine sands can also be excellent in home gardens, but plants growing in them will need to be watered fairly frequently. Soluble fertilisers will need to be added frequently in small doses, otherwise you will lose much of the added fertiliser. Slow-release fertilisers will be useful.

You would consider modifying your sand only if:

- Your plants rapidly run out of water.
- Your soil is water repellent. Water repellence can be overcome for some months through the application of wetting agents. Details are given on p. 113. Such applications will probably not be necessary if you add clay to your sand.
- You need to make frequent applications of soluble fertilisers or use expensive slow-release fertilisers if your plants are to thrive.

Organic matter seems to just vanish (because there is no clay to protect it).

You can convert the top 15–20 cm of sand into a sandy loam or loam through addition of a clay soil. You need to add a volume of clay soil equal to about one quarter of the volume of sand being treated. This will give the final topsoil mixture a clay content of 15–20%. Use a clay topsoil if possible. Subsoils usually have a high ability to ‘fix’ phosphorus, so when they are used it is usually necessary to apply superphosphate at at least 100 g per square metre.

You must at the same time add large amounts of organic matter (10 cm of compost) so that microbes can begin the task of producing humus to make aggregates. The sand, clay and organic matter should be thoroughly mixed together with a rotary hoe.

You might also try increasing the water-holding capacity of a (coarse sand) soil with one of the so-called ‘water crystals’. These materials are sold as sugar-like granules that absorb and hold many times their weight of water. They slowly break down in the soil, but with the best of them you should get at least a year of increased water holding capacity.



By walking only on the paths, compaction of the soil of a vegetable garden is kept to a minimum.

Improving the structure of clay soils

Your clay soil might already have excellent structure, but if it hasn't, you should consider modifying it with sand, organic matter and gypsum.

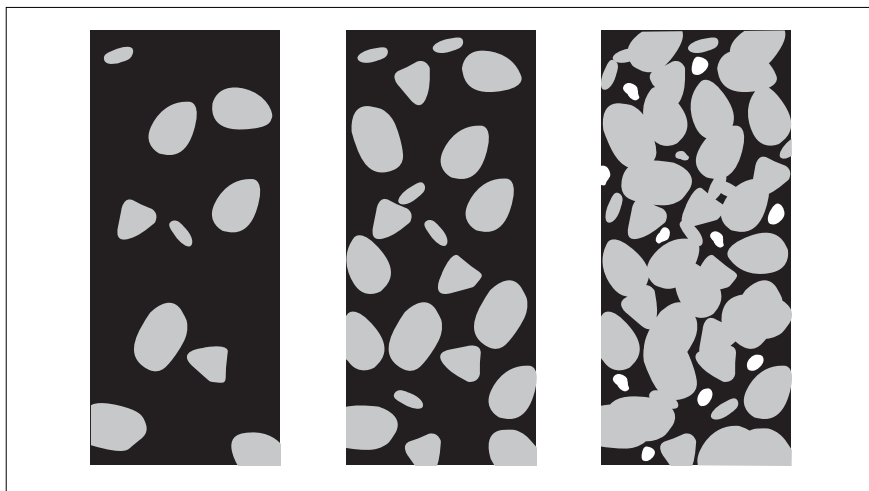
You would consider modifying a clay soil if water penetration into it is very slow, if it is difficult to dig or if it sets very hard on drying.

You can think of a clay soil as being something like porridge. Both have large numbers of small particles that are closely packed together. Close packing means that water flow into soil, and milk flow into porridge, is very slow.

Suppose we drop into a bowl of porridge a tablespoon of coarsely crushed peanuts. They will slowly sink into the porridge. Each piece will be completely surrounded by porridge. There will be no change to the ability of milk to flow through the mixture.

So it is with clay soils: a small amount of sand mixed into the soil will be completely lost and will not improve its structure or drainage. It is only after you have added sand with a volume of 60–100% of that of the soil being treated that there will be a noticeable improvement in the drainage of the soil.

Adding this much sand is expensive, so a common compromise is to mix sand into just the top 5 cm of soil, so giving about 10 cm of modified soil. Even then, it is usually not necessary to do this for the whole garden. Many hardy ornamental shrubs and trees will probably grow well on the existing soil, as long as you give them a bit of help with gypsum, organic matter and possibly



The sand has to form a framework, with clay fitting in between the sand grains, but not completely filling the pores.

drainage (p. 186). Restrict modification to areas for vegetables, and fruit trees that do not tolerate waterlogged soil.

This modification must not be done when the clay soil is very wet. You will cause serious damage to whatever structure it has if you do this. Wait until at least 3 days after rain or until the soil does not smear or pug when you dig it.

Improving soil structure with gypsum

If your soil shows the following signs of poor structure:

- is slippery and sticky when wet;
- tends to slump and get very muddy during rain;
- forms a crust on drying;
- allows only slow entry of water;
- does not break into anything smaller than large clods during digging – it is likely that application of gypsum to it will improve its structure.

Use the following test to see whether your soil will benefit from an application of gypsum.

Drop a dry soil aggregate (about 6 mm across) into a glass of rainwater or deionised water (p. 44). Take another sample of the soil in the palm of one hand, add some rainwater or deionised water, and knead the soil until all of the lumps have been broken up. Squeeze some of the kneaded soil into an aggregate about 5 mm across. Drop this into a second glass of the same water. Do not move the glasses.

Watch what happens over the first hour, and then after 24 hours. You will see one of the following.

- Some aggregates remain unchanged, even after 24 hours.
- Others fall apart within this first hour, but the smaller aggregates so formed remain where they fall.
- Others, whether they fall apart or not, slowly disperse into the water, first forming a 'halo' of clay particles around the aggregate. This halo then spreads to a general cloudiness throughout the water.

Gypsum will not improve the structure of a soil whose aggregates remain unchanged or that fall apart without dispersion during testing.

The greater the cloudiness of the water, and the more rapidly it develops, the greater will be the benefit of adding gypsum to the soil, and the higher the amount needed.

Add gypsum to your soil if the water in either of the glasses goes cloudy. Use 0.5 to 1 kg per square metre. It may be left on the surface or dug in, whichever is easiest.

How gypsum works

Cloudy water in the test just described indicates that the proportion of sodium ions on the clay particles is too high. The sodium ions prevent the particles from coming close to one another. They can be forced closer – or prevented from separating in the first place – if the concentration of any salt in the solution around them is increased.

Gypsum is calcium sulphate. It is slightly soluble in water. Adding gypsum to a soil increases the salinity of the water in it and this keeps the particles together. This effect disappears as soon as there is no more gypsum left to dissolve in the water.

Gypsum also has a more permanent beneficial effect on soil structure. Its calcium ions exchange places with sodium ions on clay particle surfaces (see p. 61). This also allows the particles to move closer together and to remain there. The displaced sodium ions move away from the particle surfaces. With enough water, they will be flushed down into the subsoil.

Use 'clay breakers'?

'Clay breaker' solutions are being sold as replacements for gypsum. The claim is that they are cheaper and do a better job at improving soil structure than does gypsum. They can increase the infiltration rate of water into a clay soil, but they cannot alter the basic cause of sodicity: only calcium (from gypsum) can do that. By all means try these solutions, but do not expect long-term remediation of sodic soils.

EFFECTS OF EARTHWORMS ON SOILS

Earthworms are good for soils; they increase plant growth because they:

- Break up organic materials and mix them into the soil.
- Help break up root mats in lawns and thick layers of leaf litter.

- Increase microbial activity in the soil.
- Increase the availability to plants of nutrients in soils and organic matter.
- Improve the crumb structure of soils.
- Increase the amount of water that can be held in soils.
- Allow better penetration of plant roots, oxygen and water into soils.

INCREASING EARTHWORM NUMBERS

Most garden soils will have at least some earthworms. They may simply have moved in from next door or they may have come in with plants or soil. Several species may come in, but eventually those best adapted to your garden will come to be present in greatest numbers.

Check the resident population by digging during the cooler or wetter part of the year, when the worms will be active and close to the surface. The absence of earthworms in dryish, unmulched soil in the heat of a southern summer tells you nothing about the actual population as it will be 50 cm or more down in the soil.

You will need to bring in several hundred earthworms from elsewhere if there are none in your soil. The best source is a nearby garden. Place them in groups of about 50 in holes scattered around the garden. Leave some food (chopped kitchen scraps, immature compost, etc.) in each hole. The worms will soon spread as their numbers increase.

An explosion in earthworm numbers is possible only if you give them the conditions they require:

- Provide them with plenty of high-quality food (p. 45). Allow plant litter to remain on the soil surface, and add more as a mulch. Bury kitchen scraps in holes 10–20 cm deep scattered throughout the garden. Apply compost to beds for annual crops. A rapid build-up in numbers can be encouraged by providing extra food via food pellets such as those fed to poultry, horses or domestic animals.
- Don't give them low-quality (low nitrogen) organics such as uncomposted sawdust.
- Ensure that the soil is always moist.
- Mulch the soil, to protect them from the heat of summer. Soil

temperatures above 25°C usually prove fatal for the earthworms of temperate regions. The drier the environment, the more rapid the death. Some earthworms of tropical areas can survive for extended periods at temperatures up to 30°C.

- Don't dig any more than is necessary. Rotary hoeing is particularly damaging.
- Don't poison them. Particularly lethal are the fumigants Chloropicrin and Metham. High levels of copper salts (from Bordeaux mixture or copper oxychloride sprays) seriously reduce earthworm populations. If you must repeatedly apply copper sprays, you should catch the drips by spreading plastic sheeting on the ground under the plants being sprayed. When applied as recommended, most herbicides have little effect on earthworms.
- Earthworms prefer to live in a light, loamy soil so the structure of heavy clay soils needs to be modified if you want large numbers of earthworms. This can be done in part by adding sand, but large quantities of organic materials should also be used. Gypsum can improve the structure of clay soils and can prevent the formation of surface crusts.

Pamper your earthworms – provide them with the right temperature and moisture and plenty of high quality food – and they will do the rest themselves. Depending on species and conditions, they may even double their collective weight every month.

Most species are tolerant of pH values within the range 4.5 to about 8, with the greatest number of species being present in soils with pH values in the range 5–7.4.

Earthworms are usually not harmed by fertilisers. The extra plant growth produced by fertilisers increases the return of organic matter to the soil, thereby providing more food for earthworms and so leads to an increase in their numbers. The only exceptions to this beneficial effect of fertilisers are when the drop in soil pH produced by ammonium fertilisers is not corrected by lime and when an excessive application (of either 'chemical' fertiliser or 'hot' organic fertiliser) temporarily makes the soil too salty for earthworms.

DIG OR NO-DIG?

When you come to think about it, digging is rather daft. For most of the time that plants have been growing on earth they have not had the 'benefit' of soils



Weeds: plants in the wrong place.

that have been dug/cultivated by humans. But then if you think a bit further, you will realise that in their native habitats many of our garden plants grew in soils that were deep, fairly rich in organic matter and well cultivated by earthworms and other soil animals.

The benefits to be had from digging are said to be:

- to control weeds;
- to provide a seedbed of suitably fine tilth;
- to break up clods;
- to relieve compaction;
- to improve aeration in the root zone;
- to incorporate organic matter into the soil

Digging can do all of these things, but often reality can be rather different:

- Digging creates weed problems by bringing buried seeds to the surface and so into conditions that enable them to germinate. They do no harm if they remain buried.
- Digging is beneficial when it breaks clods and compacted soil, but the damaging effects of repeated digging often outweigh this benefit. Digging

breaks many aggregates apart, so exposing to attack by microbes the organic matter that binds them together. Cultivation reduces the level of organic matter in a soil: repeated cultivation steadily destroys a soil's structure.

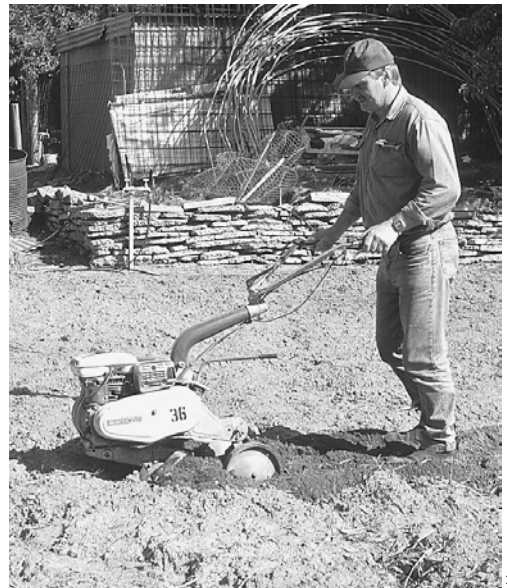
- Digging may provide a short-term improvement in aeration, but with deteriorating structure, the benefits become less and less as the years go by.
- If the digging is by rotary hoe, it is likely to create a compacted layer at the base of the tilled soil. The aggregates in the tilled soil are pulverised. If you must rotary hoe, do it only when the soil is fairly dry and then only once and lightly.
- Digging a clay soil when it is wet can cause a complete breakdown of structure. A soil is probably too wet for cultivation if water can be seen glistening on the surfaces when the soil is broken between the fingers.

We can still maintain excellent structure and tilth with annual or more frequent digging in our vegetable garden if we maintain a high level of organic matter in the soil, but this organic matter can also allow us to greatly reduce the amount of digging or give it up altogether.

DEFINITION OF A NO-DIG GARDEN

A no-dig garden is one in which you do not dig the soil, but your plants still grow in the soil itself and in a mulch layer that sits on it.

Some no-dig systems advocate the covering of the soil with a layer of newspaper and growing in hay/straw/compost beds placed on top of the soil. This artificial system makes minimal use of the riches in the soil itself and replaces them with the nutrients in organic matter that has often been removed from farm soils. This author has often wondered about the sustainability (and ethics) of organic gardening systems that rely on hay, straw and animal manures that should have been allowed to return to farm soils. The use of composts made from materials that would otherwise be buried in landfills is a totally different matter.



Owners of large vegetable gardens need help, but over-tilling the soil will damage its structure.

By all means use this type of no-dig system if all you have is concrete or a soil that is a good imitation of it, but please, not if you have soil that can be improved.

A sensible no-dig system aims to use and improve the soil of the site.

CONVERTING TO A NO-DIG GARDEN

That part of a garden that will be permanent shrubs and trees, whether ornamental or fruit, will automatically be no-dig. Set it up by following the guidelines that start on p. 35–38 and 139.

This section is really about the vegetable patch and beds for annual plants. They have traditionally been dug once or twice each year.

If the topsoil of your garden is compacted, cloddy, poorly drained or inclined to crust, or if there is a hardpan (compacted layer or layer in which the particles are cemented together) in the subsoil, you will need to do some work before you can have a no-dig garden. You must dig so that you can stop digging.

You need to dig a large amount of organic matter (a 10–15 cm layer) into compacted, cloddy and poorly drained topsoil. You may also need to add gypsum and/or sand, as discussed above. You will need to double dig to mix organic matter into a hardpan in the subsoil. That is really hard work, but you will only have to do it once! An occasional crop of lucerne or lupins will push root channels into the subsoil and so maintain the good structure that your organic matter has started to give it.



Essential tools for managing garden soils: hoes, shovel, trowel, forks, spade, weeder, mattock, sledge hammer.



An American snail bait dispenser/trap. Cans and other small containers placed under bushes and mulch can also be used as hideaways from which snails can be collected.



Raised beds on concrete are useful where tree roots invade the soil below.

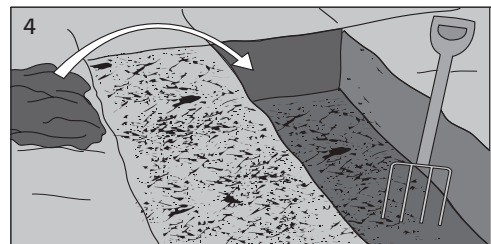
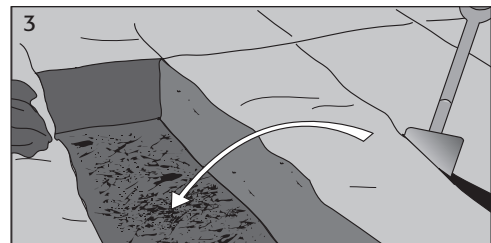
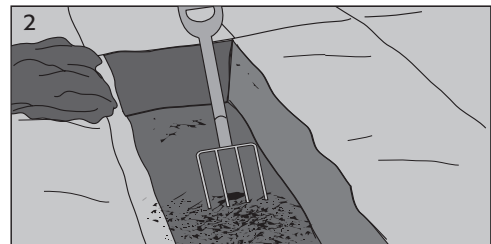
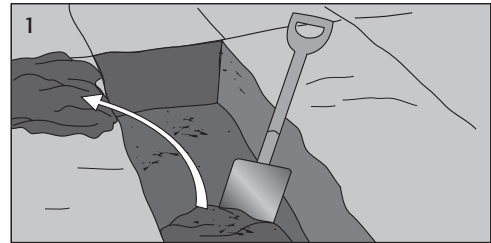
If your soil is very rocky, you may have to grow in beds built onto its surface. A layer of newspaper spread on the soil will smother weeds and will eventually rot to allow roots access to the soil below. No other barrier materials should be used.

For soils that already have good structure, all you need to do is clear away the existing vegetation, perhaps use a non-residual herbicide, such as those containing glyphosate, to kill the weeds, and loosen any areas of compacted soil. An alternative to herbicide is to remove to the compost heap a thin layer of soil/turfgrass, with its countless seeds. In summer you could kill more seeds by solarising (p. 40) the soil under clear plastic.

It is best that you mark out where paths will be and restrict your walking to them. Repeated walking on the beds will compact the soil. In some soils this compaction may completely overcome the beneficial effects that organic matter, no digging and earthworms are producing in the soil.

You may wish to transfer topsoil from paths to the beds, so raising them slightly above their surroundings. After a bit of levelling of the surface of the bed, you are ready to plant. Holes for seedlings can be made with a trowel. Furrows for seed can be made with a hoe.

Mulch can be applied to the area between seedlings immediately after planting, but mulching should be delayed until seeds have sprouted. Keep the mulch well away from the seedlings themselves as close



Double digging is hard work, but it is an essential first (probably once-only) step in preparing soils with compacted, impervious subsoils for a garden. Deep ripping by machinery can replace double digging where access is possible.

1. Dig a trench to spade depth. 2. Fork the lower surface of the trench as deeply as possible. 3. Incorporate thoroughly matured compost into the lower soil. Include gypsum if testing shows that it is needed (see page 26). 4. Put the top layer of soil from the second trench over the forked layer of the first trench. 5. Fork the surface of the lower layer of the second trench; add compost and gypsum; and fill it with the topsoil from the first or third trenches.



Weed control mat being used under bark mulch.

contact may lead to their death through damping off. Keep the thickness of mulch to that suggested on p. 75.

The mulch will aid in weed control, but if weeds do become a problem, you should consider laying weed control mat between plants. Never use plastic film; it reduces water and oxygen entry into the soil and can kill plants.

Over several years the structure of your undug soil should gradually improve through the action of plant roots, their dead residues, earthworms and the organic matter that they move down from the mulch. But in some soils, it is possible that a light digging every few years is needed to maintain good structure.

A final thought: slugs and snails love mulch. You will need to set traps for them or scatter bait.

CONVERTING A BUILDING SITE INTO A GARDEN

No matter what design you have in mind, there are a number of essential steps in the preparation of soil during landscaping, p. 47.

- Clean the site. Remove debris and weeds. Remove soil that is heavily contaminated with mortar and concrete washed from builders' tools.

- Roughly grade the area. You may need to stockpile your topsoil so that you can use it to cover exposed subsoil once you have graded the surface of the subsoil.
- Test the drainage in several parts of the area. In each area, dig a hole 15 cm deep or just into the surface of any layer of clay in the subsoil. Add water to a depth of 50 mm. After this has soaked away, add a further 50 mm depth of water. Repeat several more times. Record the time it takes for a fifth lot of water to soak away.

Fifty mm of water will soak into well-drained soils in less than 3 hours. You should seriously consider installing a drainage system if the water takes longer than 10 hours to soak away.

- Thoroughly mix any layer of coarse sandy material with the soil above and below it.
- Install a fixed irrigation system, if you are having one. You might be able to install some of the pipes for an irrigation system in trenches dug for a drainage system.
- Now improve the soil by applying gypsum, lime, organic matter and fertilisers, as discussed on other pages.
- Build walls and paths.
- Give the area its final levelling and contouring in preparation for planting.

PLANTING TREES AND SHRUBS

Some simple precautions taken when planting trees and shrubs will greatly increase the chance that a plant will survive and thrive.

TIME OF PLANTING

- Trees and shrubs that grow vigorously in the warmer part of the year (e.g. citrus, *Camellia*) are best planted at the beginning of this warm period.
- Deciduous plants (e.g. roses) are best planted a month or so before they start to put on new growth.
- Native shrubs and trees can be planted at any time in gardens where water is readily available. Plantings where water cannot be supplied are best made early in the rainy season.

THE PLANTING HOLE

- Prepare the planting hole a little before planting time.
- Dig the hole a bit deeper than the depth of the rootball.
- Loosen the soil around the hole if it is very compacted.
- Holes augered into wet clay soil may have slicked sides. These must be roughened if roots are to be able to penetrate into the soil.
- Thoroughly wet the soil in and around the hole by repeatedly filling the hole with water if the soil is dry (p. 46). This will not be necessary if the whole soil is already wet.
- Ensure that the soil surface surrounding the planting hole to a distance of 40–50 cm is free from weeds. Keeping the area weed-free is essential if early tree growth is to be rapid.

A warning: If, when you are digging a planting hole you find that you are digging into very heavy clay that looks as if it drains very slowly, you must not plant without checking as follows. Put a 50 mm layer of water in the bottom of the hole. If it takes longer than several hours to soak away into already moist soil, you can expect that any plant you put into the hole will be drowned during wet weather.

Digging down a bit deeper may allow you to break through into a more permeable layer below. If not, you will need to plant into soil mounded above the current soil surface, or you will need to provide drainage from each planting hole to a lower level. In any such area, citrus must always be planted on a mound.

PREPARING THE PLANT

- Remove all roots protruding through holes in the pot or tube.
- Just before planting, soak the rootball so that it becomes thoroughly wet. Include wetting agent in the water (1 mL concentrate per litre of water) so that the rootball is easy to rewet should it become dry.
- Remove the pot or tube.
- Examine the outside of the rootball. If the roots generally run straight from top to bottom, there is no need for further action. But for young trees, any roots that are circling around the outside of the rootball must be either cut through or pulled from the rootball. Remove any that are

circling around the base of the rootball. Make several vertical cuts into the rootball to cut other circling roots further up the rootball. *Failure to remove circling roots will condemn the plant to death in six to eight years as the now enlarged circling roots will choke it to death.*

- This attention to circling roots is less critical with shrubs than it is with trees, but the cutting of major circling roots is still desirable (p. 46).
- Suspect that advanced trees raised in pots will have circling roots buried deep inside their large rootballs. Sever them by cutting right through the lower two-thirds of the rootball, so forming a 'butterfly' of the rootball. This is rather brutal, but it is essential if you want the tree to thrive.

PLANTING AND AFTER-CARE

- Insert a fertiliser 'pill', two teaspoons of controlled-release fertiliser or some organic fertiliser into the soil below where the rootball will sit.

Lower the rootball into the centre of the hole.

- If necessary, fill in some soil under it to ensure that the top of the rootball is level with the intended soil surface.
- Partly fill the remainder of the hole with soil.
- Add some water and puddle the soil so that good contact is made between rootball and soil.
- Fill the rest of the soil into the hole and firm it gently around the rootball.
- Smooth the new soil surface to the same level as the top of the rootball.
- Form a basin around the planting hole so that water applied to the young tree does not run away.
- Add more water to settle the soil in around the rootball.
- Apply mulch out to at least 40–50 cm from the trunk.
- Whether or not more water is needed depends on the weather. In the rainy season, further watering should not be necessary with hardy species. At other times, watering should be as frequent as was necessary in the nursery. That could be every day or two to several times in two weeks. Water stress is the main cause of death in newly planted shrubs and trees.

- Keep the area weed free to at least 50 cm from the trunk.
- Protect the plant from insects and caterpillars.
- The plant's root system will expand by 1–2 metres each year.

HOW TO ASSESS SOIL BEFORE YOU BUY IT

The quality of soil offered in soil yards ranges from excellent to abysmally poor. You should check that on offer before you buy it.

- Check its pH, to make sure that it is not too acid or too alkaline for the plants you want to grow.
- If its pH is above 8, you should try to get some idea of its total lime content. Buy some of the hydrochloric acid that is used to lower the pH of swimming pool water. Put a couple of drops of it onto the soil. Very vigorous fizzing (due to the release of carbon dioxide as the lime is dissolved by the acid) indicates a high (and perhaps unacceptable) lime content (p. 47). A small amount of fizzing indicates that there is some lime present. Such a soil will be suitable for many garden situations.
- Determine its texture, as described on p. 19. Silty soils (they feel silky) can give many problems. Very sandy materials (e.g. mixtures of compost and sand) may be suitable for raised beds and large tubs, but their poor water holding ability means that plants in them must be watered frequently. Within a couple of years, mixtures of sand and compost deteriorate into water-repellent sand that is difficult to manage. The presence of some clay in the mixture will allow it in time to develop a normal soil structure. The clay will also allow better retention of humus.
- Check to see if it is sodic (p. 26). Rapid and heavy colouring of the water used in this test indicates that the soil is likely to slake during rain and possibly to form a crust on drying.
- Ask the supplier whether the soil complies with the Australian Standard for Soils for Landscaping and Garden use. Production according to this Standard guarantees reasonable quality.

These tests will take a little time, but nowhere near as much as is needed to correct problems caused by purchase of poor soil. Be assertive: don't be talked into accepting assurances of quality at face value.

SELECTING A GROWING MEDIUM FOR LARGE TUBS AND PLANTER BEDS

Potting mixes have been designed for use in pots with depths up to about 200 mm. They hold too little water when placed in tubs and planter beds, which are generally much deeper than this. Besides, gradual decomposition of the organic components of potting mixes causes slumping and the need to repot – something which is not easy with such large containers.

What is needed for large tubs and beds is a mineral mixture with a sandy loam or loamy sand texture. A sand to which has been added about 15% thoroughly decomposed organic matter is suitable. A single layer of shade cloth (nothing finer!) placed over large holes will prevent loss of the growing medium.

HOW TO REDUCE THE AMOUNT OF ROOT DISEASE IN YOUR GARDEN

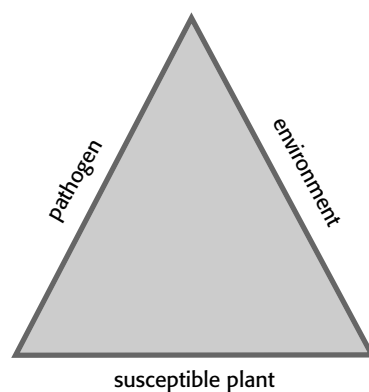
It is perfectly natural that plants are attacked by disease-causing organisms (pathogens). In natural ecosystems, disease removes old and weak individuals so that the population is continually renewed.

That is not much comfort to someone whose prize orange tree has just died. We gardeners like to feel that we are in control of our plants. Here are some guidelines for improving the chances that your plants will survive and thrive.

For a plant to be attacked there must be some pathogens near it. A small population of a particular pathogen will usually not harm a plant if it is growing vigorously. But if for some reason it becomes stressed, it will become more susceptible to attack. But even then it may not be attacked if the environmental conditions are not favourable to the particular pathogen. This is the disease triangle: pathogen, susceptible host and favourable environment are all needed.

We can minimise attack on plant roots as follows.

- Ensure excellent drainage. That means giving your soil an excellent structure, as discussed earlier in this chapter, and/or installing a drainage



The disease triangle.

system. Many root rots have their origins in a period of very wet weather when oxygen supply to roots was restricted. Nothing may have been seen then, but during hot weather, wilting followed by death shows that the root system had been severely damaged.

- Ensure that your plants are never placed under heavy stress. Drought in hot weather is a common stress. Another stress is that caused by failure to water in an application of soluble fertiliser. Another stress is lack of food. Starved plants can be just as stressed as over-fed ones.
- Mainly grow plants that are adapted to your environment. It is commonly found that those plants that most readily succumb to root diseases, and to diseases of their tops, are being grown well outside their normally preferred environment. Thus, plants native to deep sands readily get root rots in heavier soils. Some plants from alkaline soils tend to be unthrifty on acid soils.
- Apply ample amounts of organic matter. The ways in which soil organic matter helps control root diseases are discussed on p. 109.
- Rotate crops in soils used for vegetables and bedding plants. Growing the same or similar crops year after year in the same soil can lead to the buildup of populations of pathogens of that crop. A common rotation is leafy crop, root crop, legume, leafy crop.
- If root rots and nematodes still damage your plants, you should consider solarising the soil next summer. Dig the soil and break up all clods. Smooth its surface with a rake. Water it thoroughly. Tightly cover it with a sheet of thin, clear plastic (p. 48). Make sure that the edges of the plastic are firmly held down so that heat trapped under the plastic cannot escape. Leave the plastic in place for 5–6 weeks in a hot summer, longer in a cool summer. The sun's heat trapped under the plastic should by then have killed most of the nasties in the soil. Daytime temperatures of up to 55°C can be achieved in summer.
- You can also try Neem oil, as it has been reported to kill nematodes.



Costas Theodorou



Nick Mahjzok

Most plants form liaisons with mycorrhizal fungi in the soil. **Top:** Fruiting bodies ('toadstools') of a mycorrhizal fungus. **Bottom:** The mycorrhizal roots of a eucalypt.



Yellow Earth soil from Queensland. These porous soils have formed from siliceous materials through heavy leaching under mild climatic conditions and with extended periods of partial waterlogging.



H.C.T. Stace *et al.*, in *Handbook of Australian Soils*

The excellent structure of the topsoil of this Terra Rossa soil from Coonawarra, South Australia, is obvious even in this photograph.



To test for the need for gypsum, take small aggregates of soils to be tested ...



... and drop them into deionised water.



Dispersion of clay from the soil on the left indicates a need for gypsum.



Bruce Cockcroft



Bruce Cockcroft

The application of large amounts of fertilisers, organic matter, gypsum and lime to this peach orchard in the Goulburn valley has led to an enormous population of earthworms and a much-improved soil structure.



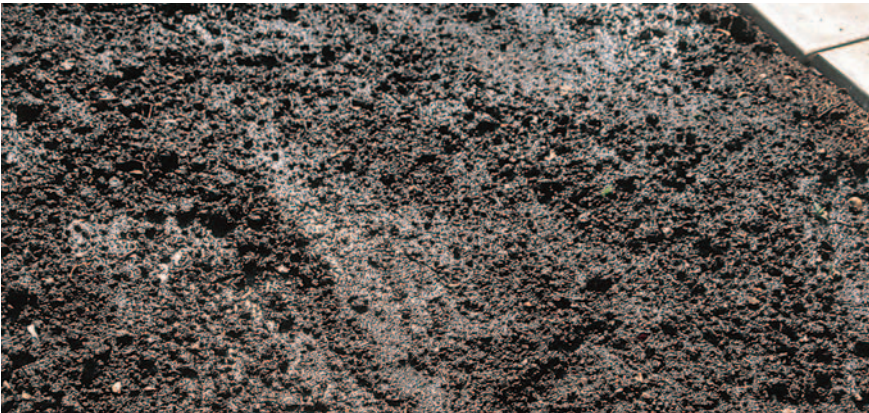
When planting trees or shrubs, the soil must be thoroughly watered both before and after planting. Circling roots must be removed from the base of the rootball and cut through at the sides.



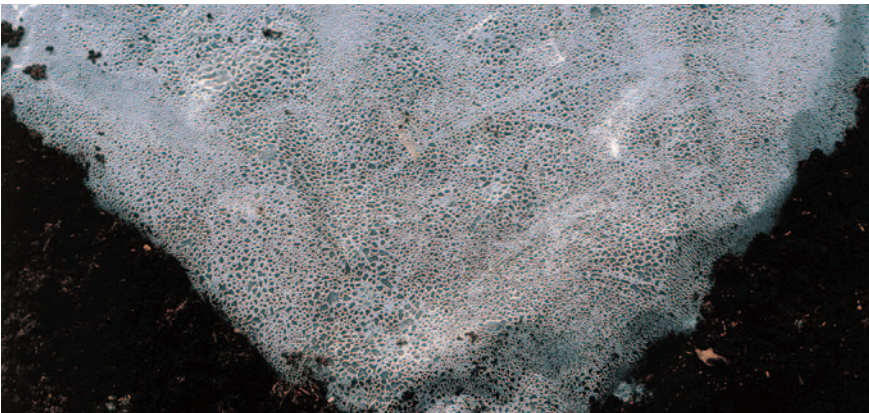
Top: This soil contains much lime. **Bottom:** Let's hope that the landscaper removes the lime-soaked soil and relieves compaction before making the garden here.



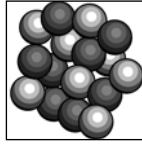
When solarising soil, first smooth its surface ...



... then irrigate it to wet the top 300 mm ...



... then cover with clear plastic sheeting.

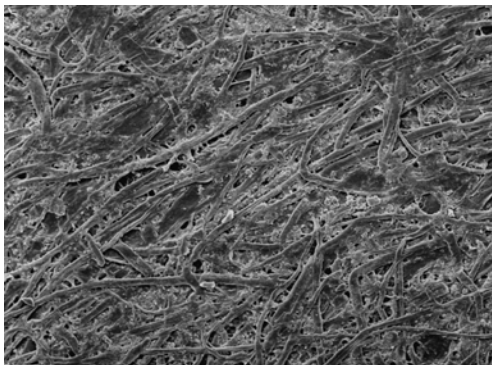


3 Chemistry for gardeners

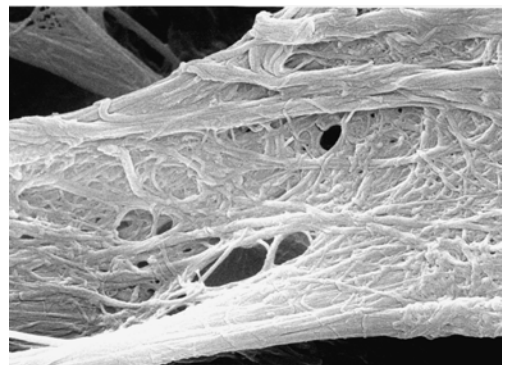
HAVE YOU EVER WONDERED?

- What is meant when soils are said to be acid or alkaline?
- What happens to fertiliser that you apply to your soil?
- What, apart from water, plants get from soils?
- Why some soils form crusts and some do not?
- Why humus is so good for soils?

For answers to these and many more questions, it helps to know just a little bit of chemistry. That little bit of chemistry will make it much easier for you to look after your plants and to quickly find answers to problems you are having with them. Go slowly and you will soon be saying: 'Ah-ha, so that's how it works.'



Surface of a sheet of paper, magnified 29 times, showing wood fibres with kaolin clay particles between them.



Detail of a single fibre showing cellulose fibrils, magnified 14 250 times.

ELEMENTS AND ATOMS

The surface of this page appears smooth, but when viewed through a magnifying glass (20–30 times magnification) it looks quite rough. The surface is a jumble of fibres that were once part of a living tree. If you had used a much more powerful microscope (say one giving a magnification of 15,000) you would be able to see that each fibre is composed of strands of cellulose.

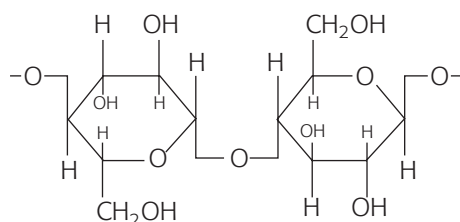
Looking with an even more powerful microscope (magnification 10 million or so) would show that each strand of cellulose is made up of atoms of carbon, hydrogen and oxygen arranged in repeating patterns.

Carbon, hydrogen and oxygen are *elements*. We, and everything around us, are made from combinations of elements. There are over 100 elements.

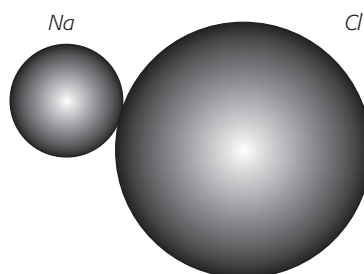
You will be familiar with elements such as gold, silver, copper, and oxygen. The tiniest pieces of elements are called atoms. All the atoms of an element are the same, but they are different from the atoms of each of the other elements. Atoms are very small: something like 8 million fit one high on a line 1 mm long. Atoms can only be changed or destroyed in atomic bombs and atomic reactors.

Chemistry is the study of elements, the ways they behave, the ways they combine with one another and the properties of these combinations.

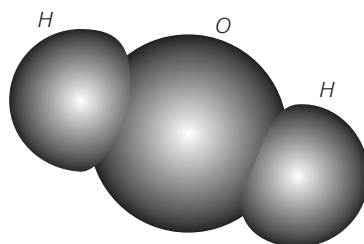
Sometimes we meet an element by itself – a bag of dusting sulphur, a bar of gold, a cylinder of oxygen. Sometimes we meet elements in mixtures.



The arrangement of atoms in cellulose.



Common salt (NaCl)



Water (H₂O)

Arrangements of atoms in common salt (sodium chloride = NaCl) and water (H₂O).

Air is a mixture of the elements nitrogen, oxygen, helium and argon (and more); steel is a mixture of iron, carbon, silicon (and more).

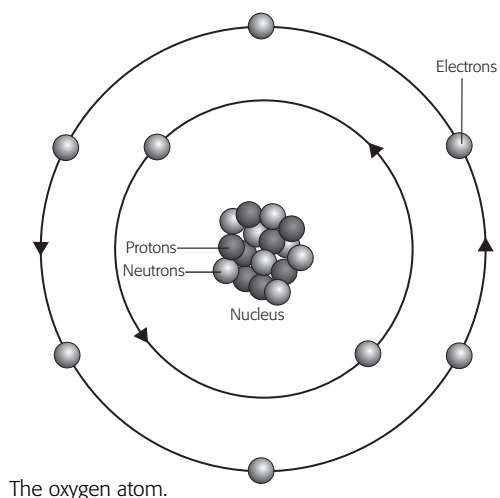
More often, however, we meet elements in combination with one another. These combinations are called *compounds*. The smallest piece of a compound is called a *molecule*. An example of a simple compound is common (table) salt. Each molecule of salt (sodium chloride) contains one atom of sodium and one atom of chlorine, joined together, so it is written NaCl. Each water molecule contains two atoms of hydrogen and one atom of oxygen (H₂O).

Chemists have a shorthand way of writing the name of an element, using the first letter of its name in Latin and, if necessary, one other letter. Here is a list of the elements that are essential to plant growth (plus others, in brackets, that have beneficial effects on at least some plants).

Element	Symbol
Carbon	C
Hydrogen	H
Oxygen	O
Nitrogen	N
Phosphorus	P
Potassium (Kalium)	K
Sulphur	S
Calcium	Ca
Magnesium	Mg
Iron (Ferrum)	Fe
Copper	Cu
Zinc	Zn
Manganese	Mn
Boron	B
Molybdenum	Mo
Chlorine	Cl
Nickel	Ni
(Aluminium)	(Al)
(Cobalt)	(Co)
(Vanadium)	(V)
(Silicon)	(Si)
(Sodium (Natrium))	(Na)

A PEEP INTO THE STRUCTURE OF ATOMS

We need just a little information about atoms as a basis for understanding the important properties of soils (p. 53). All atoms (of all elements) have a central core – the *nucleus* – which is composed of *neutrons* and *protons*. (We ignore here the findings of physicists that even these are composed of goodness knows how many smaller bits. These findings do not affect the chemical behaviour of atoms.) Whirling around the nucleus are one or more *electrons*. The reason why gold is different from silver, and



The oxygen atom.

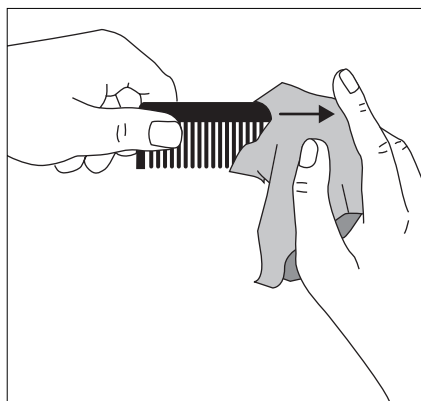
oxygen from nitrogen, is that each has a different number of protons, neutrons and electrons in its atoms.

Protons and electrons are electrically charged. By convention, it is said that protons are positively charged and electrons negatively charged. In the atom itself, the numbers of electrons is exactly the same as the number of protons, so the numbers of positive and negative charges are equal, making the atoms and the element electrically neutral.

ORGANIC COMPOUNDS

Compounds that have carbon, hydrogen and oxygen as their main elements are called *organic compounds*. Sugar is just one of many commonly used organic compounds. Each molecule has 12 carbon atoms, 11 oxygen atoms and 22 hydrogen atoms. The cellulose of the paper of this page is another example. Each molecule contains many thousands of carbon, hydrogen and oxygen atoms.

These compounds were called ‘organic’ because of early ideas that they were found only in living things. While natural compounds such as sugars, cellulose and proteins are organic compounds, the term now covers a vast range of synthetic compounds such as plastics, drugs, pesticides, dyes and detergents, which are all combinations of carbon, hydrogen, oxygen and other elements.



Rubbing a plastic comb with cloth allows it to attract to itself hair or small pieces of paper. The plastic has acquired some electrons from the cloth and so is negatively charged until these electrons find new homes in atoms that have lost electrons.

INORGANIC COMPOUNDS

The many thousands of compounds not based on carbon are referred to as *inorganic*. Most chemical fertilisers are inorganic, as are all soil minerals.

When inorganic compounds are formed, the atoms of one element ‘grab’ one or more electrons from the atoms of another element. That makes the atoms of each element electrically charged. Such electrically charged atoms are called *ions*.

Those ions that have gained electrons (and so have become negatively charged) are called *anions* (pronounced an-eye-ons), while those that have lost electrons (and have become positively charged) are called *cations* (cat-eye-ons). Cations and anions can be made from single atoms or they can be combinations of atoms, as shown in the table below.

Ions are very important because:

- It is mainly as ions that plant nutrients are held in soils or are present in hydroponics solutions;
- It is mainly as ions that nutrients are taken up by plants;
- The physical properties of soils are greatly influenced by the types and proportions of cations present on particle surfaces;
- Whether a soil is acid or alkaline is determined by the concentration of hydrogen ions in it;
- Most of the ‘salts’ that we are familiar with in our homes are combinations of ions, as the table shows.

Common name	Chemical name	Ions	Chemical formula
Baking soda	sodium bicarbonate	$\text{Na}^+ \text{HCO}_3^-$	NaHCO_3
Epsom salts	magnesium sulphate	$\text{Mg}^{2+} \text{SO}_4^{2-}$	MgSO_4
Calgon	sodium hexametaphosphate	$\text{Na}^+ \text{HPO}_3^-$	$\text{Na}_6(\text{HPO}_3)_6$
Sulphate of ammonia	ammonium sulphate	$\text{NH}_4^+ \text{SO}_4^{2-}$	$(\text{NH}_4)_2\text{SO}_4$
Potassium nitrate	potassium nitrate	$\text{K}^+ \text{NO}_3^-$	KNO_3
Hydrochloric acid	hydrochloric acid	$\text{H}^+ \text{Cl}^-$	HCl

ACIDITY AND ALKALINITY

We all know something about acids and alkalis.

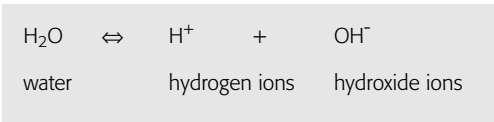
Vinegar is a weak solution of acetic acid. The liquid in our car batteries is very strong sulphuric acid. Swimming pool owners add hydrochloric acid to their pools to keep the water slightly acid. To make soap we need some vegetable oil or fat and a strong alkali such as caustic soda (sodium hydroxide). Limestone (calcium carbonate), builders’ lime (calcium hydroxide) and dolomite (a mixture of calcium and magnesium carbonates) are other familiar alkaline materials.

	pH
Gastric juices	1.0
Coca Cola	2.0
Vinegar	2.5
Orange juice	3.5
Banana	5.0
Plant sap	3.5–5.5
Milk	6.5
Blood	7.4
Eggs	7.8
Soap lather	9.0
Washing soda	10.0

Those readers who have been gardening for a while will recall having seen statements such as: Some plants can grow only in very acid soils. Some soils are highly alkaline and only specially adapted plants can be grown in them.

What is it that makes some soils acid and others alkaline? For an answer, we start with water.

Water is H₂O: each molecule has two atoms of hydrogen and one atom of oxygen. In a glass of pure water, just a few of these molecules split into ions:



The numbers of hydrogen (positively charged) and hydroxide (negatively charged) ions are exactly the same, so the water remains neutral. (Otherwise we would get an electric shock every time we had a shower or drank a glass of water!)

Adding an acid to the water increases the concentration of H⁺ in it (and lowers the concentration of hydroxide ions). On the other hand, adding an alkali reduces the concentration of H⁺ (and increases the concentration of hydroxide ions).

So acid soils have higher concentrations of hydrogen ions than do alkaline soils.

The shorthand way of writing about acidity and alkalinity is through the symbol ‘pH’. (For those who really want to know, ‘pH’ stands for ‘negative

logarithm of the concentration (potential) of hydrogen ion (H^+). You will find a more complete explanation of pH in the book *Growing Media for Ornamental Plants and Turf**.)

The pH scale runs from 0 to 14, with a pH of 7 indicating neutrality (neither acid nor alkaline). Values of pH lower than 7 indicate acidity; values above 7 indicate alkalinity. Therefore, the more acid a soil, the lower its pH; the more alkaline a soil, the higher its pH.

Note that because the pH scale is logarithmic, a pH of 4 is 10 times more acid than a pH of 5 and 100 times more acid than a pH of 6, and so on.

WHY PH IS IMPORTANT

Just as our hands are burnt by caustic soda or hydrochloric acid, so plants are damaged by very high and very low pH. The absolute acid limit for plant roots is about pH 4, and the alkaline limit is about pH 9. Between these limits, different plants have different ideal ranges.

Plants that evolved in areas where the soils are naturally very acid (say pH 4.5) do not tolerate soils with pH values much over 6. Those from slightly acid soils manage very well in soils with pH values in the range 5.5 to about 7, and even up to about 7.5. Plants from areas of alkaline soils can usually be grown on slightly acid (pH 6.5) soils, but soils that are very acid (less than about pH 5.5) may cause them problems.

The main reason for this effect of pH on growth is that change in pH changes the availability to plants of nutrient elements in soils.

* K.A. Handreck and N.D. Black. University of New South Wales Press, Sydney, 4th Edition 2001.



Several commonly available acids: acetic, sulphuric and hydrochloric.



Blueberries can only be grown on very acid soils.

For example, the availability of the nutrients manganese, boron, copper and zinc increases greatly as pH drops below 5. There is a risk that plants will be damaged by toxic concentrations of one or more of these elements in very acid soils. On the other hand, these low pH values make it difficult for some plants to get enough calcium and molybdenum from a soil.

In contrast, as pH rises above neutral, the availability of iron, manganese, copper and zinc drops. Plants not adapted to high pH are unable to get enough of these elements, particularly iron and zinc (p. 65), and their leaves show it.

The best pH range for many of the plants that we grow in our garden soils is 5.5 to 7.5. There is no need to try to adjust the pH of our soil to the 'ideal' of 6.5 that is often mentioned in books. Many plants will grow well at even higher pH values. But the so-called acid-loving plants such as rhododendrons will have difficulty with any pH over about 6, unless there is an abundance of organic matter in the soil.

The best pH range for plants growing in potting mixes is a little lower than that for natural soils. This is because potting mixes are now mainly organic materials such as composted pine bark, composted sawdust, coir fibre dust and peat. Plant nutrients are most readily available from organic materials in the pH range 5 to 6.5, with an 'ideal' of about 6. See p. 265 for details.

Soil micro-organisms also have their preferred pH ranges. For example, *Rhizobium* bacteria (which live on the roots of legumes and fix atmospheric nitrogen) do not infect the roots of host plants at pH values below about 5.

The main action that can cause soils to become more acid is the application of acidifying fertilisers such as ammonium sulphate. Application to soils of wood ash, ground limestone, dolomite, cement dust, alkaline (hard) water, and composts to which liming materials were added during making will all raise soil pH. Effluent water from laundries that use detergent powders is very alkaline. Their high sodium content seriously damages soil structure (p. 194).

HOW TO ALTER SOIL PH

TO RAISE SOIL PH

Apply ground limestone (calcium carbonate), builder's lime (hydrated lime; calcium hydroxide) or ground dolomite (calcium and magnesium

carbonates) to the soil surface. Dig it in wherever possible. The quickest response is obtained with builder's lime.

The amount to use depends on the amount of change in pH needed and on the texture of the soil. As a rough guide, for one unit change in pH (e.g. 5 to 6) of the top 10 cm of a soil, apply limestone at about 100 g per square metre to sandy soils, about 200 g per square metre to loams and up to 400 g per square metre to clay soils. Allow at least a couple of months for builder's lime to finish its work and perhaps a year for ground limestone. Measure the pH again then and add more lime if the pH is still too low.



Raising soil pH with ground limestone.

TO LOWER SOIL PH

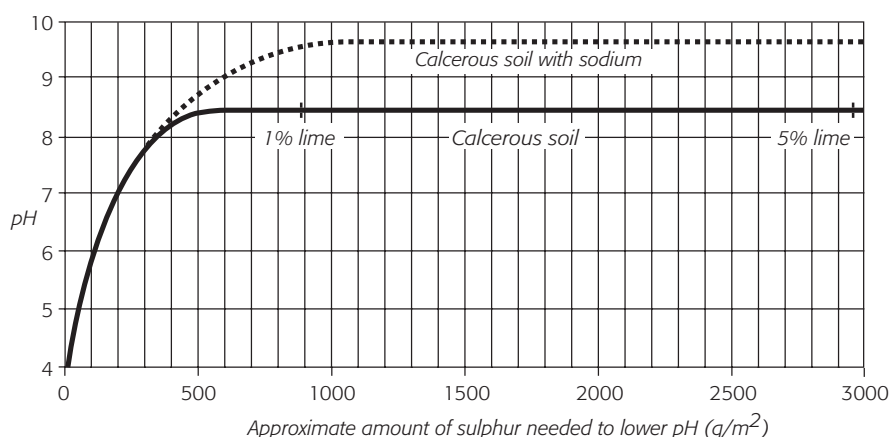
Soils with pH values over 8.4 usually contain several per cent limestone. All of this limestone has to be dissolved by acid before the pH of the remaining soil will start to drop (see the diagram on p. 58). That is expensive and not easy. It is usually rather fruitless to try to lower the pH of such soils.

You can, however, lower the pH of soils that have a pH of about 8 or less. Sulphur (available as agricultural sulphur or dusting sulphur) is the cheapest material to use. For a drop of one pH unit in the top 10 cm. of soil, apply about 25 g per square metre to sands and up to 100 g per square metre to clays.

Sulphur works because it is converted by bacteria in the soil into sulphuric acid, which increases the concentration of hydrogen ions in the soil and so lowers pH.

Iron sulphate can also be used. You will need about double the weight of iron sulphate as you need of sulphur to get the same change in pH. However, the high salinity of iron sulphate means that only one third of the total amount to be added should be added at one time. Water heavily, wait a week and check pH before applying more.

Alum (aluminium sulphate) should not be used to lower soil pH as it can seriously interfere with the availability of phosphorus. But it and iron sulphate are useful if a high phosphorus content in the soil is causing or



For example, to lower the pH of the top 10 cm of soil:

1. From 8 to 6.5 would take about $350 - 150 = 180 \text{ g/m}^2$
2. From 8.4 (5% lime) to 6.5 would take about $2960 - 150 = 2810 \text{ g/m}^2$

aggravating iron deficiency in a plant (see p. 146). The aluminium and iron will reduce the availability of the phosphorus in the soil. Alum can be used to acidify the soil under hydrangeas whose flowers must be blue. The blue colour is an aluminium compound.

Peat can be used for acidifying small areas. One cubic metre of peat has the same acidifying power as about 600 g of sulphur.

MEASURING SOIL PH

Take time to collect a sample that properly represents the soil being tested.

- For a heap of soil at a garden supplies yard, take several handfuls of soil from different parts of the heap and mix thoroughly. The sample to be tested should be taken from this mixture.
- For a garden bed, the soil you test should be made from at least 5 and preferably 10 separate samples collected from across the area. Take each sample to spade depth. Subsoils should be tested separately from surface soils. Thoroughly mix the 5–10 samples, in the process breaking up any clods.

1. Using a colorimetric kit

Follow the instructions given in the captions on p. 66.

2. Using an electronic pH meter

Into a clean plastic container of about 500 mL capacity place about 2 cm depth of soil. Dribble onto it a little deionised or rain water. Stir the mixture with a kitchen knife. Keep adding water until the soil is a thick slurry. At the right moisture content the slurry just slides off the knife when it is tilted, but water does not collect on the soil surface in the container.

Press the electrode of the pH meter into the slurry and read the pH value. Rinse the electrode with water between samples and before storing.

3. Don't use probes

Probes can be very inaccurate. They can be as much as 2 pH units wrong. They can mislead you, so they are not recommended. If you own one, smash it with a hammer before throwing it into the rubbish bin.



Example of inaccurate readings given by probe "pH meters". The electronic meter shows a pH of 5.85, but the probe reads about 7.

CLAY AND HUMUS

At some time in your life you will almost certainly have experienced at least one of the following:

- Dirty shoes and hands after gardening or handling thoroughly matured compost;
- Slipperiness when walking on clay soils;
- Muddy water in a farm dam or in the local river during a flood or as a result of construction or logging upstream.

Each of these situations has something to do with the very smallest particles in soils – clay and humus. Despite a few unpleasant experiences with wet clay (mud), in soils, small really is beautiful, and certainly very, very important.

WHY CLAY AND HUMUS ARE IMPORTANT

Clay and humus are important because:

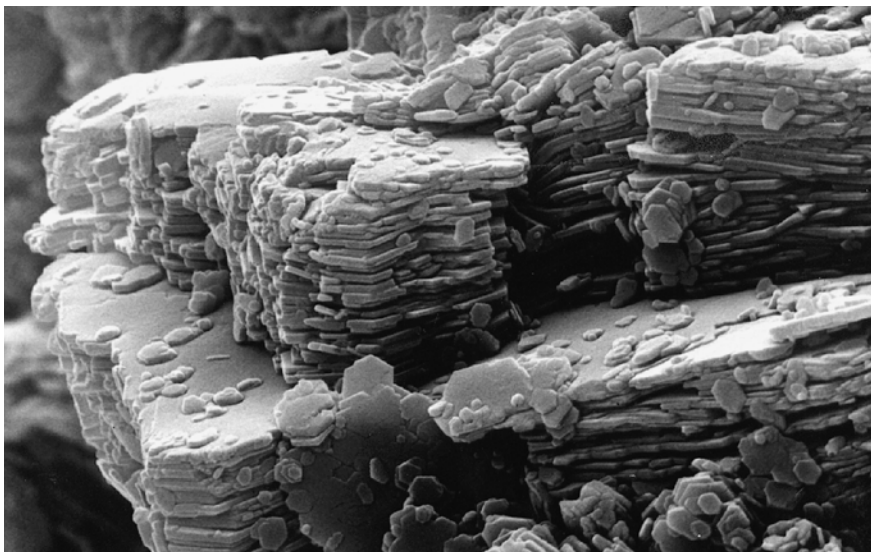
- They control the supply of many nutrients to plants;
- They reduce the loss of plant nutrients from surface soils in water percolating through the soil;
- They dominate the ability of a soil to maintain a stable pH;
- They have a major effect on the physical properties of soils, particularly the ability to hold and supply water and air and to provide a good environment for root growth.

HOW SMALL?

The largest particles of clay are only 0.002 mm wide. That means that 500 of the largest and 200 000 of the smallest will fit side-by-side on a line 1 mm long.

One effect of this smallness is that when clay or humus is shaken in pure (salt-free) water, they remain suspended in the water for a very long time.

However, when a muddy stream hits the sea the particles in it quickly clump together, because of the effect of the salt in sea water. Muddy water in roadside puddles and farm dams indicates that the water is not salty.



Looking like cliffs in outback Australia, these tiny plates of the clay mineral kaolinite are an important component of many soils. Magnification x 10,500. [Stewart McClure]

Another important thing about the smallness of clay particles is that it means that clay has an enormous surface area. You can get a feel for this by thinking about buckets filled with stones 50 mm across, 5 mm gravel, coarse sand or fine sand. Even though the volume of each is the same, the fine sand clearly has a much greater total surface area than do the other materials.

Clay particles are much, much smaller than sand grains. The total surface area of one gram of clay is in the range 10–800 square metres. The range for humus is 800–900 square metres per gram. By contrast, coarse sand has a surface area of about 0.01 square metres per gram.



The power of shrinking and swelling in smectite clays can also be seen in the cracking of the walls of buildings if their footings have not been designed to suit the soil.

CLAY MINERALS

All clay particles are minerals that contain silicon, oxygen, iron and aluminium, together with smaller amounts of other elements such as calcium, sodium, potassium and magnesium. The clay minerals belong to one or other of two basic groups of minerals known as the kaolin and smectite groups.

A main difference between these two groups is the way they behave as they dry out and become wet again. Each smectite mineral particle tends to shrink as it dries and swells again as it gets wet. When multiplied by millions, we see this behaviour as the formation of cracks in clay soils during dry weather and the closing of the cracks in wet weather.

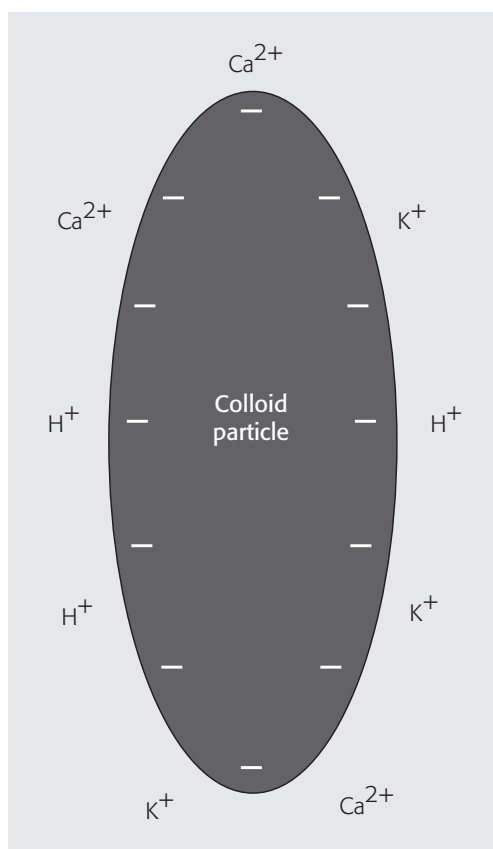
WHAT ELSE IS IMPORTANT ABOUT CLAY AND HUMUS?

Think of a person and a life-size statue of that person. They look alike, but one is much more active than the other. That activity has to do with the types and arrangement of atoms inside the person.

Clay minerals and finely chopped rock are just like person and statue: the rock just sits there taking up space, while the clay interacts vigorously with its surroundings.

That interaction by clay (and humus) comes about because of the types and arrangement of atoms inside each particle. The silicon, aluminium, iron, oxygen and other elements that make up clay minerals are arranged in such a way that there are some negative electrical charges left over at the surface. These negative charges attract positively charged ions (cations) to their surfaces.

The main cations involved are those of the elements calcium, magnesium, hydrogen, aluminium, sodium, potassium and nitrogen (as ammonium). They are fairly loosely held on and near clay mineral surfaces. If we add a fertiliser containing ammonium and potassium ions to a soil, some of them will replace ions such as calcium and magnesium on clay particle surfaces. In other words, some of the ammonium and potassium ions exchange places with calcium and magnesium ions. That is why these ions are called 'exchangeable cations'.



Colloid particles are always accompanied by a cloud of cations that exactly balance the number of negative charges on their surfaces.

SUMMARY

- The smallest particles in soils are called clay and humus.
- These particles have very large surface areas.
- The chemistry of clay and humus leaves their surfaces with large numbers of negative electrical charges.
- The negatively charged surfaces of clay and humus particles attract positively charged ions of elements such as calcium, magnesium, sodium, hydrogen, potassium and ammonium.
- Cations readily exchange places with one another.

CLAY, HUMUS AND PLANT NUTRITION

Now we get to an explanation of how clay and humus affect soil fertility and physical properties.

- The exchangeable cations on the surfaces of clay and humus particles are held sufficiently firmly so that only small numbers of them are removed in water percolating through the soil.
- Loss of soluble nitrogen is much less from soils rich in clay and humus than from sandy soils because ammonium ions produced during the decomposition of organic matter or added to a soil in a fertiliser are held by clay and humus.
- The higher the humus content of a soil, the greater is its ability to hold nutrients and to supply them to plants.
- As minerals are weathered in soils, the released nutrient elements join the exchangeable cations on clay and humus surfaces.
- Most of the sulphur in soils is present either as gypsum or as part of humus. If there isn't much gypsum in a soil the humus is the main source of sulphur for plants.
- Roots remove cations from the surfaces of clay and humus particles by secreting hydrogen ions that exchange places with them. These hydrogen ions will be neutralised by hydroxide ions released when plants take up anions.
- The pH of a soil decreases as the proportion of hydrogen ions on surfaces increases.

BUFFER CAPACITY

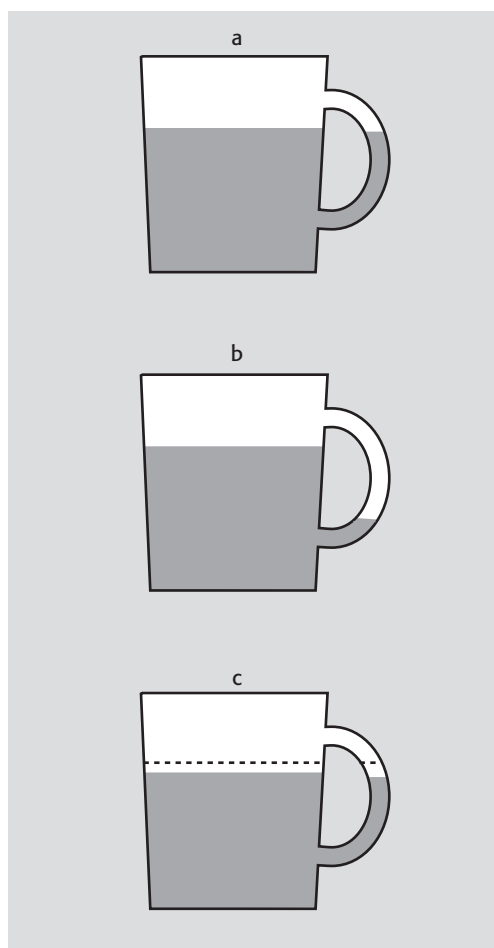
It is possible to grow excellent plants of high quality in solutions of chemical salts without any soil. Soil-less culture, or hydroponics as the system is called, is widely used in the commercial production of vegetables, especially in Europe. Soil, and soil organic matter, are not essential for growing plants.

But there are big differences between growing in soils and growing in nutrient solutions. The nutrient solution has to be topped up from time to time, and

with the right mixture of salts. Often the pH of the solution changes very rapidly. Automatic metering equipment or frequent checks of the solution are needed for success.

These rapid and large changes in nutrient supply and solution pH do not happen in soils because of clay and humus. These hold a reserve of nutrients and they stabilise pH: they buffer the soil against these changes in much the same way in which a wide reservoir reduces the effect of removing water from an attached narrow reservoir.

In soils, humus has a particularly large capacity to buffer out pH changes. The more humus present the greater is the soil's ability to act as a buffer against changes.



Buffer capacity may be understood by looking at liquid in a hollow-handled mug (a). If the handle is almost emptied of liquid (b), the overall drop in height of the liquid in the mug is small (c). The large volume of the mug has acted as a buffer that has kept change to a minimum.



As pH rises above neutral, the availability of iron, manganese and zinc drops. **Top:** Hydrangea leaf showing iron deficiency symptoms. **Bottom:** Zinc deficiency is common in citrus growing on neutral to slightly alkaline soils.



To measure soil pH with a colorimetric test kit:
1. Add indicator solution ...



2. Mix to a thick paste ...



3. Apply barium sulphate powder ...



4. Use the colour chart to read the pH.



Recycling is natural. **Top:** A carpet of litter is a sign of a healthy forest. **Bottom:** Fungal fruiting bodies on a decaying log.



Top: Mulches protect the soil surface and reduce loss of water through evaporation.
Bottom: Pine bark nuggets make an effective and long-lasting mulch.



Recycling via composting. **Top:** Gardeners with large gardens will find composting easiest in large enclosures such as this. **Centre:** Compost heaps and bins teem with life. **Bottom:** Add water to materials to be composted until you can squeeze water from them with a firm handshake type of squeeze. They are too wet if water drips from them without squeezing or with only a light squeeze.



Arthur Winn



Fauser All-States Worms, Adelaide

Top: Vigorous decomposition is taking place in these frequently turned compost heaps.
Centre: A backyard earthworm farm such as this can recycle most of the kitchen scraps from a small household. **Bottom:** Tiger worms make short work of organic wastes.



Albert Rovira



Albert Rovira

Organic matter improves soil structure. **Top:** This wheatland soil, cultivated in the traditional way, has become dense and crusty. **Bottom:** When the crop is sown without cultivation, earthworms proliferate to give the soil an excellent structure.



If a water drop sits on the surface of dried soil for longer than 85 seconds, action should be taken to improve the wettability of the soil. Soaking times of greater than 4 minutes indicate very severe water repellence.



4 Dealing with dead plants

While the aim of all gardeners is to keep their plants alive as long as is possible, inevitably plants, or parts of them, die. Something must be done with the remains.

RECYCLING IS NATURAL

An old leaf falls from a tree in a forest; a branch breaks off in a storm; a koala munching on eucalypt leaves relieves itself, so does a caterpillar as it chomps on some grass on the forest floor. Excreta, old leaves and branches – these are the wastes of a forest.

But these wastes are not carted away to some distant dump or sewage works. They fall onto the soil in which the plants are growing (p. 67). There they form the food of countless bacteria and fungi (p. 67), which in their turn produce further wastes. These wastes are the humus of soils and the nutrients that can again be taken up by plant roots to make new leaves and branches.

Every successful gardener copies this natural recycling. Our organic wastes can be:

- Used as mulch
- Buried
- Fed to poultry or rabbits



Dead plants should be fed to living plants, not rubbish bins.

- Composted (see page 77)
- Fed to earthworms (see p. 92).

RECYCLING VIA MULCH

A mulch is a layer of material spread over the surface of a soil. The main types of mulching materials are:

- Organic materials that decompose readily – straw, hay, partly matured compost, leaves, animal manures, seaweed;
- Organic materials that decompose more slowly – pinebark, wood chips, twigs and thin branches chopped into 10–30 cm lengths (p. 68);
- Minerals such as pebbles, gravel and crushed bricks;
- Synthetic materials such as weed control mats.

Mulches have many effects. They:

- Reduce losses of water by evaporation, and so:
- Allow plant roots to more effectively use the top few centimetres of soil, which is usually the richest in plant nutrients;
- Protect the soil surface from heavy rain – and so reduce the risk of crusting and erosion;
- Slow the flow of water across the soil and so increase the proportion moving down to where roots can use it;
- Change the temperature of the underlying soil. Organic mulches keep the soil cooler than it would have been without a mulch. Plastic mulches often increase average soil temperature. This can benefit plant growth in winter but may kill plants on hot summer days by cooking their roots.
- Help control weeds (provided that the organic mulches do not themselves contain weed seeds).
- Keep the fruit of crops such as strawberries and cucumbers off the soil and so clean and less liable to disease.
- Improve soil structure and release nutrients as they decompose, if they are readily decomposable organic materials.

ORGANIC MULCHES

Most, but not all, organic wastes can be used as mulches. Anything that is likely to attract flies should not be left on the soil surface. Heavily diseased wastes, such as tomato and zucchini bushes at the end of a growing season, should not be used as mulch. Their use is likely to increase disease problems during the next growing season.

Mulches made from thick layers (more than about 3 cm) of lawn clippings or autumn leaves are not recommended, because they may pack down into a dense mat that allows little water to reach the soil. Rather, such materials should be mixed with bulky materials such as prunings and corn stalks that have been chopped into 10–30 cm lengths.

The ideal thickness of an organic mulch depends on how coarse it is.

- Fine compost and fine bark: 2–3 cm (but note that fine compost makes an excellent seed bed for weeds)
- Coarse compost and coarse bark (up to 1 cm pieces): 3–4 cm
- Chipped tree trimmings: 4–6 cm
- Bark nuggets, chopped sticks: 6–8 cm

Dry soil as a mulch

Light cultivation of bare soil a day or so after watering or rain will break capillaries between the surface soil and that underneath. The surface soil will dry to form a mulch that can cut evaporation from the soil underneath by as much as half.

These thicknesses will reduce evaporation from the soil surface by 70–80%. (Evaporation is reduced because the mulch creates a layer of still, humid air above the soil. This humid air greatly reduces the rate at which water molecules diffuse out through the mulch.) Thicker mulches are less effective: they hold so much water that only the heaviest rain and prolonged sprinkling is able to reach the soil.

A mulch must not form a completely watertight layer. That would not only prevent all rain water from reaching the soil but will also prevent vital oxygen from reaching plant roots.

Sawdust can be used as a mulch, but during decomposition of the bottom layer there will be some reduction in the amount of soluble nitrogen available to plants. Including about 20% poultry manure in the sawdust, or applying 150 g ammonium sulphate per 30 litres, should prevent any problems. Plants are likely to become quite deficient in nitrogen if sawdust is dug into the soil.

Sawdust should be detoxified and partly decomposed by composting (with urea and/or poultry manure) before it is used as a mulch.

In cold areas, plants mulched with organic materials grow more slowly in late winter and early spring than do unmulched plants or those mulched with black plastic, because of lower soil temperatures.

Always thoroughly wet a soil before applying a mulch. Regularly check underneath it to make sure that the soil is still moist.

Paper makes a poor mulch. It does reduce evaporation, but holes made in it for water to enter the soil soon allow it to get into a tatty mess. It is, however, a good weed killer if left on thickly for several weeks.

Keep straw away from seedlings until they are well established, otherwise toxins released from the straw during early decomposition may damage the seedlings.

Considerable amounts of plant nutrients are leached to the soil below from organic mulches such as hay, compost and grass clippings. They are both mulch and fertiliser.

Organic mulches gradually decompose and so become thinner. They should be added to annually.

RECYCLING VIA BURYING

Food scraps can be buried in shallow holes dug in the garden. They will soon be broken down by earthworms, bacteria and fungi in the soil. The nutrients in them will become available to nearby plants and the humus produced will improve the structure of the soil.

The burying should be deep enough – say 10 cm below the surface – to hide the scraps away from flies. Even deeper burial might be necessary if there is a dog in the family!

Burying is not sensible or possible if the soil of a garden bed is a mass of roots. Digging will be difficult. Citrus trees and other



Kitchen scraps buried in the garden soon rot down into humus and plant nutrients.

shallow-rooted plants will be damaged if their roots are disturbed. They will gain most benefit if the recycling is via a mulch.

RECYCLING VIA COMPOSTING

Composting is really just a method of speeding up the natural processes of rotting that take place in the litter of forests or in kitchen scraps buried in the garden. In the compost heap we can control the process to suit ourselves. Good technique ensures maximum return to our soil of the nutrients of the 'waste' materials.

Making compost is easy. Microbes have always done it in the litter layers of forests. It just comes naturally to them. Damp leaves, air and a bit of warmth is all that they need. Mind you, they do take rather a long time, but they don't have to be in a hurry.

We don't have to be in a hurry either, but most of us seem to be these days. Making compost in a hurry calls for the sort of knowledge about composting that is given from p. 81. For those gardeners who are in no hurry, here are several ways of making compost.

NO-HURRY COMPOSTING

All you need to do is to drop the materials to be composted into a bin or onto a heap of other materials in the corner of the garden. You will have useable compost in 9–12 months.

Composting in bins

1. Buy two plastic compost bins.
2. Sit them on the ground (preferably), paving blocks or an area of concrete in a part of your garden that is easy to get to without getting your shoes dirty.
3. Lift the lid of one bin and tip your kitchen scraps, lawn clippings, weeds and autumn leaves into it.
4. Continue until the bin is full.
5. Start on the second bin.
6. The contents of the first bin should have rotted down to compost by the time you have filled the second bin.



Compost bin made from recycled plastic bottles by Rib Loc Australia.



This bin has large numbers of small aeration holes in its sides.

Composting in a heap

1. Set aside a small area of the yard for the compost heap. The area should be hidden from general view as it may sometimes look a bit untidy.
2. At its simplest, the area will be a corner where two fences intersect or where a shed meets a fence.
3. Slightly more complicated are large bins holding one or two cubic metres of materials. These can be made from old bricks, recycled timber – not painted with lead-containing paint – old railway sleepers, wire mesh and wire mesh lined with plastic film.
4. Most gardeners find that galvanised iron is the cheapest (usually free) material for containing a compost heap (p. 69). There is some risk in the use of galvanised iron: the composting materials will dissolve some of the zinc from the galvanising. Over the years the concentration of zinc (a heavy metal) in your soil will be increased, perhaps to a level that will seriously reduce the effectiveness of nitrogen-fixing organisms in it. For most gardens the risks are probably slight, but will be greatest for those whose soils are sandy and acid. If you have been using galvanised iron for many years, you should ensure that the pH of your soil is always above 6.
5. Dump your organic 'wastes' onto the composting area or into the bin.
6. Keep on doing so until the heap is large enough to be left to rot by itself.
7. Start a second heap.



The Gedye compost bin.



The Little Aussie Rotter compost bin.

Some extra details

- If you desperately need some compost, you can carefully lift one side of a bin and ferret some out, or dig in under the edge of a heap. The compost may be a bit immature.
- Anything that has been alive can be added to compost bins and heaps. That includes eucalypt leaves and newspaper. They are a bit slow to decompose, but they do eventually.
- Dry materials such as straw and autumn leaves must be moistened before going into the bin or heap.
- When food scraps make up a large proportion of the additions to a compost bin or heap, it is essential that from time to time you add a light sprinkling of sawdust/lime mixture (1:1 by volume) (keep a container of it nearby) and/or soil. The sawdust will mop up excess water and provide carbon to balance the nitrogen of the scraps.
- You will find that the level of material in the bin or heap keeps falling as the materials decompose. For a while you might think that you are tipping your scraps into a bottomless pit, but gradually the bin will fill or the heap will grow.
- Try to remove weeds from your garden before they seed. Seeds added to a compost bin or heap usually won't be killed and so you will just spread them around your garden as you use the compost.

- There is no need to add bought 'activators' to speed up composting. These materials are of no benefit when compost is made mainly from kitchen scraps and garden wastes.

Earthworms in compost heaps and bins

Earthworms eat large quantities of soil and organic materials; they are very effective in reducing the size of bulky litter and incorporating it into soils. They can also grow well in cool compost heaps (p.69) and so hasten the composting process. They may invade the heap from the soil below, but you can add worms bought from a fishing supplies store or dug up from elsewhere in the garden.

However, earthworms cannot survive the high temperatures of turned compost heaps. If you want to add worms to such a heap, wait until after the temperature drops.

But it seems that there is little need to add worms to this sort of heap. Micro-organisms have already done the work that earthworms might otherwise have started. Getting the compost out onto the garden where earthworms can mix it into the soil where plant roots are has greater merit.

An alternative or addition

An alternative to bins and heaps for those with enough space is to feed all food scraps to hens. The hens mix inedible materials with their excreta and the sawdust of the deep litter. From time to time some of the litter can be removed and used in the garden or incorporated into a compost heap that would otherwise be a bit low in nitrogen, phosphorus and potassium. Feeding food scraps to hens gives you a double return – eggs and recycled nutrients.



When buying a mulcher, choose the most powerful one you can afford.



Hens: dual-purpose recyclers.

MAKING COMPOST IN A HURRY

To make compost in a hurry – say in a few weeks – you will need:

- At least one cubic metre of organic materials with the right balance of food for microbes;
 - To add just the right amount of water to the organic materials;
 - Microbes;
 - Plenty of oxygen in the heap;
 - Food, because *you* will be getting plenty of exercise.
1. Select an area of soil on which to make a free-standing heap. The total area must be twice the size of one heap so as to allow room for turning. Alternatively, construct two or three bins side-by-side from concrete blocks, railway sleepers or recycled timber (p. 70). Each bin should be of at least one cubic metre capacity.
 2. Assemble the materials to be used. You must have at least one cubic metre. Any smaller amount will usually not heat up enough to make composting fast enough to give you compost in a few weeks.
 3. Shred materials that are too big.
 4. Moisten dry materials, as discussed below.
 5. For a rapid start to composting, mix all of the materials together before making the heap.
 6. Start to build the heap by placing a 10 cm layer of the mixture onto the area where the heap is to be built.
 7. Sprinkle the materials with water if they are still not wet enough.
 8. Repeat steps 6 and 7 until you have used all of your materials or the heap is big enough.
 9. Some gardeners may not have the space or energy to mix all of the materials before making the heap. If that is you, build the heap using alternate layers of high-nitrogen and high-carbon materials. The thickness of the layers should be in about the ratio given in the table on p. 84 for the chosen recipe. For example, in the second last recipe, a 9 cm thick layer of lawn clippings and weeds will be followed by a 3 cm layer of dead leaves, about 1 cm of poultry manure and 3 cm of sawdust.

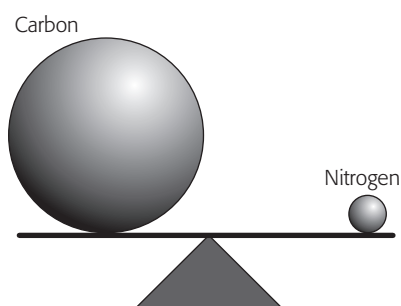
10. Any amendments such as lime (see p. 84) or superphosphate can be added as light sprinklings onto each of the thickest layers.
11. The heap should be left undisturbed for 3–4 days, during which time it will heat to at least 50°C if it has been made properly.
12. Turn the heap onto a nearby area of soil or into an adjoining bin (p. 70). Fluff the materials up as you do this. Add water as need is shown by a squeeze test. (p. 85)
13. Repeat the turning approximately every three days until the 14th day.
14. By this time the heap will probably not be as hot as it was earlier. Turning frequency can be reduced to about once a week.
15. You will have useable, somewhat coarse compost in about 3 weeks. The longer you leave the heap thereafter, the finer will be the resulting compost.

GETTING THE BALANCE RIGHT

You must realise that microbes are fussy. They tend to 'go slow' if the food supply is not to their liking. They will work fast only if they are given high quality 'rubbish'. That means that they need just the right balance between carbon (C) – to allow them to increase their populations and to keep themselves warm – and nitrogen (N), to make the protein of all their offspring. The right balance is a C/N ratio (%C divided by %N in the organic materials used) of about 30 or less. The tables on the next pages show you how to get the right balance of materials for your compost heap.

All organic materials contain carbon. There is usually more than enough for even the fussiest microbes. Supplying enough nitrogen for rapid composting is a main key to success.

The main way of supplying enough nitrogen to microbes in compost heaps is to include organic materials that contain high concentrations of nitrogen (see the table). These can be supplemented with nitrogenous fertilisers. Organic gardeners will usually restrict themselves to high-nitrogen organic materials.



A compost heap will work well when its materials contain about 30 times as much carbon as nitrogen.

Approximate nitrogen contents of several groups of materials that can be used in compost heaps.

A carbon (C) content of 50% has been assumed, as most natural organic materials contain close to this percentage.

	%N	C/N
Group A: Very high carbon (low nitrogen) material		
Sawdust	0.11	450
Group B: High carbon (low nitrogen) materials		
Straw	0.5	100
Dead leaves	0.7	70
Paper	0.27	170
Group C: Moderate nitrogen materials		
Lawn clippings, weeds	2	20
Food scraps	2.5	15
Animal manures	2.3	20
Urine (human)	about 1% (w/v)	
Group D: High nitrogen materials		
Blood and bone	5	7
Feathers, hair	10	4
Manure of grain-fed animals	6	8

Some might use the nitrogenous fertiliser urea. It is a component of urine so it is considered to be natural by many organic gardeners, even though bought urea will have been made in a fertiliser factory.

RECIPES FOR COMPOST HEAPS

The aim is to make a mixture of materials with a C/N ratio in the range 25–30. On page 84 are some examples of such mixtures. All proportions are by volume.

Use these recipes as a guide for making suitable mixtures with the materials you have. Don't be too fussy about the proportions; mixtures that are a bit different from those listed will usually work well.

Provided that the C/N ratio is right, it is not essential that animal manures are included. Urea can be used to supply extra nitrogen if high-nitrogen organics are not available in sufficient quantities to compost large quantities of leaves or other low-nitrogen materials. Use about 50 g urea per bucket of leaves if you have no other source of nitrogen.

Examples of mixtures (parts by volume) that will compost rapidly.

Group A	Group B	Group C	Group D
1	-	12	-
-	1	5	-
0.5	2	6	-
-	3	5	-
-	4	3	0.5–1
1	1	3	0.5–1
1	1	3	Urine*

**1.5 L per 20 L materials (provides about the same amount of nitrogen as does 30 g urea)*

SHOULD I ADD OTHER NUTRIENTS?

Micro-organisms do need abundant supplies of the other nutrient elements, with phosphorus being particularly important. It is often worthwhile adding some extra phosphorus to compost heaps that are supposed to heat quickly, especially if leaves are a major component.

Phosphorus is provided by poultry and pigeon manures, bone meal, blood and bone, rock phosphate and superphosphate. Use only light sprinklings of the last two as more than about 2% by weight can inhibit decomposition. The availability to plants of the phosphorus in rock phosphate will be considerably increased within the compost heap.

The other nutrients needed by micro-organisms are usually present in sufficient amounts in any typical domestic compost heap.

The only other additives to consider are a little lime or dolomite to raise the pH of the materials (see p. 89) and some soil. The soil is not essential, but clay soil added to a compost heap will interact with the humus and so increase the amount produced. Adding this clay-compost mixture to a sandy soil will increase the ability of the sand to hold water and plant nutrients.



Compost produced in bins is improved by an occasional light dusting of lime – unless you want acid compost.

MOISTURE

Once you have assembled the organic materials, the next task is to make sure that they are wet enough, but not too wet. Grab a handful of the mixture of organic materials (p. 69). They are too dry if you cannot squeeze water from them. Dry materials must be moistened before they are added to the heap. Very wet materials need to have drier materials mixed with them.

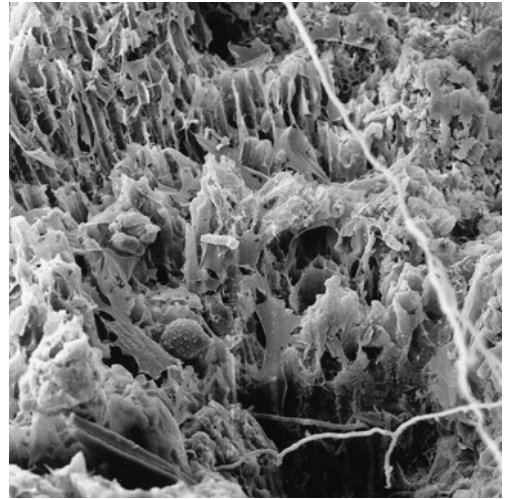
At the right moisture content, the materials will have around 50–55% by weight of water. Composting will be very slow indeed if the materials have only 35% water: only dry-rot type fungi manage to do much at this moisture content. Very wet compost heaps give off foul odours.

Keeping a compost heap moist enough is one of the main problems facing composters in Australia. Repeatedly moisten the heap in hot, dry weather. Cover it temporarily if it looks like getting too wet during prolonged rain.

MICRO-ORGANISMS

Some hundreds of different micro-organisms – mostly bacteria, fungi and actinomycetes (branching bacteria) – are involved in the decomposition of organic materials. They and their spores are everywhere – in the air, on this page, on living plants. They remain inactive until conditions for their growth and reproduction are just right. As a plant begins to age and die, it is invaded by microbes and so the process of decomposition begins.

Almost always, there are ample numbers of microbes already present on organic materials for composting to start quickly. Many hundreds of thousands of successful compost heaps are constructed each year without any preparations supposedly containing special ‘activator’ organisms. Proprietary preparations which are claimed to increase the rate of composting have been repeatedly shown to be of no benefit if the materials of the heap have been chosen carefully.



Stewart McCure

Scanning electron micrograph showing extensive decomposition of cells in a fragment of plant material from a compost heap. Magnification: x 330.

The best way of supplying an abundance of microbes to materials that you think might not have enough is to add to the new heap about 5% by volume of some of the finished compost of the previous heap. That is standard practice in some large commercial composting operations. Adding the relatively small number of microbes in commercial preparations (if indeed there are any there at all) is a bit like adding a pebble to a rock slide. The results are the same with or without the pebble.

Occasionally, a commercial activator may be seen to aid composting. This will usually be traced to the nitrogen in it. Such a response is more cheaply had by using urea, poultry manure or some other high-nitrogen organic materials.

OXYGEN

Some microbes need oxygen, just like we do. They are called aerobes – microbes that need air. Some microbes do not need oxygen. They are called anaerobes. Aerobes decompose organic materials at a much faster rate than do anaerobes. Another important difference is that the smell of aerobic decomposition is that of leaf litter or rich organic earth, while the smell of anaerobic (no-oxygen) decomposition is like that of a badly run pigsty. The foul odour of a poorly aerated compost heap will soon tell you to smarten your act. The odours are mainly from organic acids and several sulphurous compounds such as rotten egg gas. Flies will be attracted to the smell.

If you want fast, sweet-smelling composting, you must make sure that there is plenty of oxygen in the heap at all times.

Good oxygen supply is ensured as follows.

- Something like 30–50% of the heap should consist of materials that do not pack down into a solid mass. Straw, pieces of vegetation chopped into 5–10 cm lengths, irregularly shaped leaves and the material produced by shredders fit the bill. These materials form a framework that allows easy entry of air.
- The heap should not be walked on during making. Any compaction caused by such walking will collapse some of the channels through which air can enter the heap.



Fluff up the composting materials during turning.

- During making and turning of the heap, fluff up the materials so that many channels for air movement are created.
- Turn the heap as given in points 12–13 on page 82.
- Make the heap small enough to allow movement of air to most parts of it. You probably won't run into this problem as heaps have to be a few metres wide and over two metres high before air movement into a heap of well-chosen materials is hampered too much.
- Perhaps most important of all, don't add water beyond the squeeze point (p. 85).

Trouble shooting for compost makers

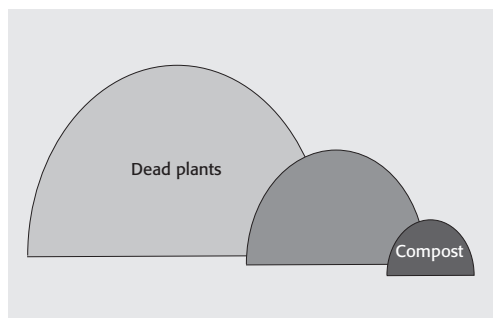
Symptom	Causes	Treatments
Foul odours	Too wet	Add dry materials (of right C/N ratio); turn the heap more frequently; cover during rain if necessary.
Heap won't heat	Too wet	See above
	Too dry	Add water during turning.
	Too small	Remake using more materials, or accept slow composting
	Too acid	Check pH if possible. Add lime if there is a high proportion of food wastes in it.
	Incorrect balance	Check what you used against the table of materials (see p. 84)
Heap works for a while, then stops	Too dry	Add water during mixing
	Nitrogen all used	Add high nitrogen materials

THE NOT-SO-SECRET LIFE OF A COMPOST HEAP

Within a couple of days of making a compost heap you will notice that it will start to get warm, then hot. In cold weather you will see steam rising from it. On digging into it you will notice that many of the materials are covered with grey fungal growths. As time passes, the heap will shrink, the materials will darken and the individual pieces will become hard to recognise. Eventually the whole mass will become dark brown and will take on a pleasant earthy smell. Let's look more closely at these changes.

VOLUME CHANGE

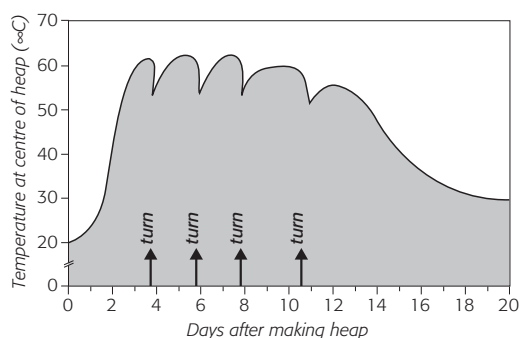
One of the most noticeable changes with a compost heap is that it keeps getting smaller. Much of the carbon of the original organic materials is used for food by micro-organisms in their life processes and ends up as carbon dioxide gas in the air. This loss causes a 30–60% decrease in dry weight of the heap and a volume reduction of around two-thirds. The nutrients of the original materials are concentrated into the remaining compost.



Difference in volume – from original organic materials to compost.

TEMPERATURE CHANGES

Heaps of moist organic materials heat up (p. 70) because much of the heat given off by micro-organisms as they feed and multiply is kept in the heap by the insulating properties of the outer materials. The interiors of large heaps soon reach 60°C and if left undisturbed can go as high as 80°C. Small heaps and small compost bins lose heat more rapidly than do large heaps – because small heaps have larger surface area to volume ratios than large heaps. In winter, large heaps are therefore more efficient than small heaps. Rapid composting in winter in southern Australia is possible only if the heap is of at least 1 cubic metre volume.



Temperature changes in a compost heap.

Scientists refer to that part of the temperature cycle below 40°C as the mesophilic stage and the stage above 40°C as the thermophilic. Marked changes occur in the microbial population as the temperature moves past 40°C. The mesophilic organisms (those that like a middle temperature range as we do) die out and are replaced by an upsurge in the population of thermophilic organisms (those that like high temperatures). Later, as the temperature drops, mesophilic organisms re-invade the centre of the heap from the cooler outer layers. Decomposition of organic materials is fastest in the thermophilic stage.

During turning for aeration, the interior temperature may drop 5 or 10°C, but it soon rises again. Some thermophilic organisms die at temperatures over 60°C, so the maximum temperature of a heap tends to be self-regulating. This high-temperature dying-off increases the time needed to finish the composting process. If you want rapid composting, the temperature of the heap should be monitored, and the heap turned or reduced in size before it reaches 60°C. Composting is most rapid at temperatures in the 45–50°C range.

CHANGES IN PH

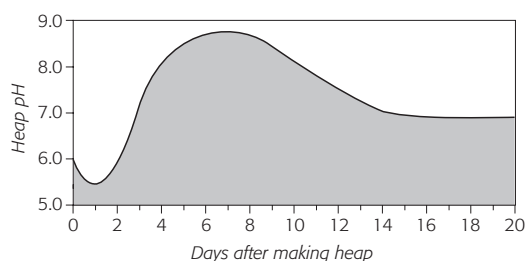
The sap of plants is acidic, so most compost heaps start off acidic. For a while they usually become even more acidic (lower pH) as acetic, citric, tartaric, lactic and other acids are produced by bacteria. These acids are slowly broken down.

As heap temperature rises, ammonia gas is produced and this usually makes the heap alkaline (often with a pH of about 8).

Composting is much more rapid in the pH range 7 to 8 than in an acid heap). The pH of the heap falls again as microbes use the ammonia to produce the protein of their bodies. Finished compost is often about neutral – sometimes slightly acid, sometimes slightly alkaline.

It is sometimes recommended that ground limestone (calcium carbonate), dolomite (mixed calcium and magnesium carbonates) or wood ash (calcium, magnesium and potassium oxides and carbonates mainly) should be added to compost heaps. These materials neutralise the acids produced and so allow more rapid arrival of the alkaline (high pH) conditions needed for rapid composting. Adding one of these liming materials can shorten the time needed for making matured compost. The extra calcium and magnesium can improve the quality of finished compost.

But caution is in order: the increase in pH will increase losses of valuable nitrogen from the heap. This happens mainly in the thermophilic stage of decomposition when the heap is alkaline anyway. Lime increases the alkalinity of the heap; this reduces the solubility of ammonia in the water of the heap, and so increases the proportion of ammonia in gaseous form. A greater proportion of the ammonia can then escape into the atmosphere.



Changes in pH in a compost heap.

Liming materials should not be used if your soil is acid and you want to keep it that way. Slightly acid compost may be of benefit when added to alkaline soils. To improve physical properties without using lime, add gypsum to the heap, again at about 1 kg per cubic metre. Gypsum does not raise the pH of the heap.

CHEMICAL CHANGES IN THE HEAP

Compost heaps are akin to complex chemical factories. Many changes take place in the course of decomposition. Even before the microbes start their work, enzymes in plant cells have started to break up proteins into amino acids. Then the micro-organisms consume all the soluble compounds – the sugars, amino acids, inorganic nitrogen (mainly ammonium nitrogen) – and start breaking up the starches (into sugar), fats (into glycerol and organic acids), proteins (into amino acids) and cellulose (into sugars) and using the bits as food. At times more ammonia is produced from proteins than the microbes can handle and some may escape. Plant nitrogen is converted into the protein of micro-organisms and eventually some is converted into nitrate, a ready source of nitrogen for plants.

Lignin, a ‘woody’ compound of the cell walls of plants, is somewhat resistant to microbial decomposition, but eventually even it is changed.

Micro-organisms in the compost heap and later in the soil use lignin and other plant components to make very large stable molecules that make up the black humus of soils. These molecules are able to join soil particles together into aggregates and so improve soil structure. As these humus components are slowly broken down over many years by other soil organisms, the various nutrient elements that they contain are released to plant roots.

MICROBIOLOGICAL CHANGES

During aerobic composting, the microbial population is continually changing. In the first mesophilic stage, fungi and acid-producing bacteria multiply on readily available foodstuffs such as amino acids, sugars and starches. Their activity produces heat and eventually the thermophiles take over in the interior of the heap. The thermophilic bacteria and actinomycetes decompose protein and non-cellulose carbohydrate components such as fat.

Thermophilic fungi thrive in the 40–60°C range but die above 60°C. They decompose hemi-cellulose and cellulose and so they are particularly important in the formation of compost.

Continuing decomposition of the organic materials gradually reduces the microbes' food supply. Eventually, the thermophilic organisms decrease their activity, heap temperature falls, and mesophilic organisms invade the interior from the outer layers that remained relatively cool during the thermophilic stage.

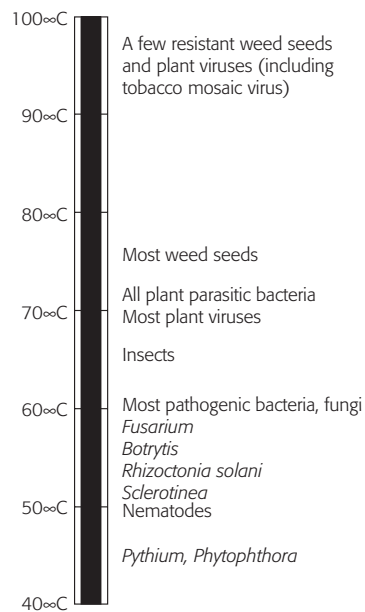
Micro-organisms decompose plant materials mainly by means of the enzymes they excrete. Enzymes are large, complex protein molecules that enable chemical reactions to take place without actually being used up themselves: they are catalysts. An example of an enzyme production system close to home is that of the salivary glands in our mouths. Saliva contains an enzyme called amylase that is able to break up starch into sugars.

In compost heaps, micro-organisms probably excrete many hundreds of enzymes that enable them to break organic materials, including each other, into smaller bits that they can use as food. For example, some organisms make an enzyme called cellulase that can break up cellulose (a major component of cell walls, and of the paper of this page) into glucose. This can then be absorbed by the organism and 'burnt' to provide energy for its life processes.

KILLING OF PATHOGENS

An important function of the compost heap is the destruction of pathogens and parasites of both plants and animals, and many weed seeds. Most are killed at temperatures of 55 to 60°C and so do not survive the thermophilic stage. Others are killed by micro-organisms. Composting at temperatures above 55°C for 3 days gets rid of most pathogens. If pathogens are known to be present initially, it is essential that you make sure that **all** materials spend some time in the hottest part of the heap.

The bacteria that produce wilts in tomatoes, the bacteria that blight beans, the fungi that cause rusts and the eelworms that attack roots can all be killed in a hot compost heap. Burning need not be resorted to for diseased plants provided they get hot enough inside



Approximate temperatures at which various organisms and seeds are killed in 30 minutes of composting.

the heap. If you cannot guarantee that these materials will be heated to 55 to 60°C for at least several days, it would be better that you consigned disease-laden materials to the rubbish bin.

Note that the seeds of many weeds will not be killed if the compost heap does not heat into the 55–60°C range.

BUYING COMMERCIALLY MADE COMPOST

Busy people may not have enough time to make their own compost. They often place their dead plants into the green organics recycling bin that is provided by their local council. The green organics are then composted in large windrows and the compost sold in bulk or bags.

When you buy commercial compost, insist that it conforms with the provisions of the Australian Standard for Composts, Soil Conditioners and Mulches. By following the provisions of this Standard, composters are able to produce compost that is free from weed seeds and plant pathogens, has minimal nitrogen drawdown, does not have high concentrations of heavy metals, is not toxic to plants and has minimal contamination. Information will be provided about its rate of use so that plants are not harmed by its salinity.

Compost that does not indicate conformity with the Australian Standard may be OK, but it may not be.

RECYCLING VIA VERMICOMPOSTING

There is another way of converting organic wastes to soil conditioner and fertiliser: let earthworms do the work (p. 70). All that you need to do is feed the worms and keep the birds away from them.

Cows produce cow dung; sheep produce sheep dung; earthworms produce castings. A bunch of earthworms (p. 70) let loose on a heap of kitchen and garden ‘wastes’ will gradually convert the ‘wastes’ into castings. The mixture of castings and remaining more-or-less intact ‘wastes’ is called vermicompost. The longer you leave the worms to do their work, the closer the vermicompost becomes to pure earthworm castings.

Castings are more highly concentrated in most plant nutrients than are the original plant materials, so the longer worms are allowed to work in a heap,

the higher will be the fertiliser value of the vermicompost. Nitrogen is often an exception to this. Much nitrogen is removed when worms are removed from the vermicompost. Usually, the concentration of nitrogen in castings is lower than it was in the raw materials, or in normal compost made from the same materials.

A well matured 'normal' compost and vermicompost produced from the same materials will usually be found to be very similar in their fertiliser value and their effects on plant growth. Composting and vermicomposting are different roads to the same goal.

Here is the information you need to produce vermicompost.



A commercial earthworm farm.

CHOOSING A HOME FOR YOUR EARTHWORMS

You will need a container or enclosure: it will keep the earthworms in and the birds out.

Match container size to the size of your proposed operation. The smallest practical containers are the foam cartons used to transport fresh fruit and vegetables. They can be obtained cheaply from your local greengrocer. Other small containers can be made from plastic garbage bins or wooden boxes. They should be about 30 cm deep. Hardware stores and garden centres sell plastic 'worm farms'. If your main purpose is to dispose of kitchen scraps, allow a surface area of about 30×50 cm (0.15 square metres) per person in the household.

Do not use metal containers. There will be enough copper dissolved from copper containers or zinc from galvanised containers to give concentrations in the finished vermicompost that could be toxic to plants.

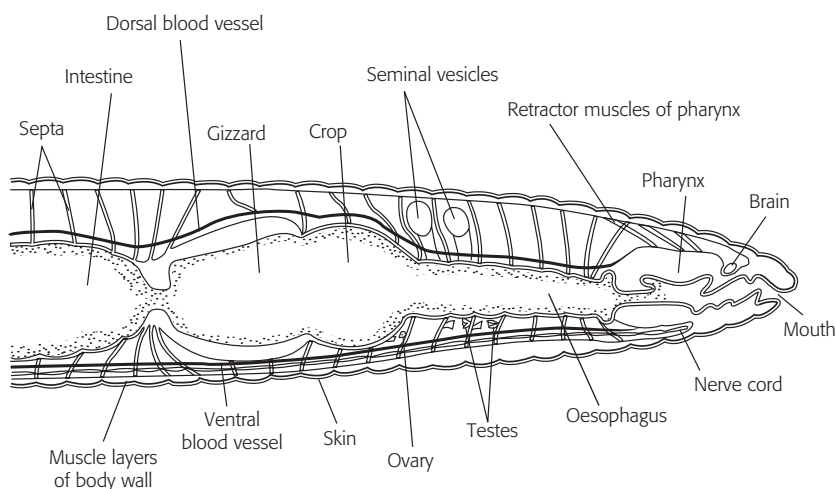
For larger operations it is best to construct raised beds about 1 metre wide and 30 cm deep. These may be placed directly on the soil, but removal of vermicompost will be easier if they are placed on concrete. Drainage holes must be provided if the base is concrete, and the beds receive rain. The holes can be every metre or so in the bottom of the walls. Even with containers that are sheltered from the rain, it is best to provide drainage holes for the occasions when you might add too much water to the bed.

SITE

A small culture bed can be kept in a back porch or verandah. As long as you maintain the culture properly, there should be no objectionable smell. Otherwise, the culture can be kept anywhere outside where it is protected from direct sun, from frosts and preferably from rain. Direct sun could increase bed temperature in summer to above that tolerated by the worms. Use shadecloth if natural shade is not available. Freezing temperatures will kill the worms and low temperatures (less than 5°C for temperate species and perhaps 15°C for tropical species) will seriously slow their rate of growth. Rain may make the bed too wet and lead to anaerobic conditions, foul odours, perhaps death of the worms, and loss of nutrients through leaching. Small beds can have individual covers, but larger operations are best conducted under cover. It is best to isolate the bed from the soil below. The earthworms in beds constructed on or sitting on soil may abscond if you do not feed them well!

TYPE OF EARTHWORMS

The earthworms used must be capable of growing fast and breeding prolifically in a rich organic environment. In Southern Australia, that means that you should choose red worms (*Lumbricus rubellus*) or Tiger worms (*Eisenia fetida*). Under ideal conditions, eight of these worms can increase to about 1500 in 6 months. In the tropics you will probably use a *Pheretima* that is common in gardens in your neighbourhood.



Some of the vital parts of an earthworm. [Drawing: Ken Lee]

STARTING

Three-quarters fill the container with bedding materials such as immature compost or a mixture of animal manure and immature compost or leaf mould. The bedding must be moistened until it is just possible to squeeze a few drops of water from a handful of bedding. The bed can be a little wetter in the summer but should be on the dry side in winter. Bedding provides your earthworms with some food and a place to live.

Start with about 50 worms per litre of bedding. This works out at roughly 500 per foam box or 2000 per square metre of larger beds. In boxes, the worms should all be added at one spot along with a supply of food. Scatter groups of worms along the full length of larger beds. Bury the food and then place the worms on the surface above it. They will soon wriggle into the bed to escape from the light. Any that don't disappear can be assumed to be dead or ill and should be removed.

The beds should then be covered to exclude light and birds and to reduce evaporation of water. Cover the bed with weed control matting. Black plastic film can be used but it must be loose-fitting so that air is not excluded from the beds. Old carpet and old hessian bags make good covers.

FOOD

Almost any organic matter can be used as food for worms in culture beds, as long as it contains at least 1% nitrogen. See the listing in the table on p. 83. Low nitrogen materials such as sawdust, twigs, bark, paper, cardboard and eucalypt leaves can be used if they are accompanied by high-nitrogen materials such as poultry manure and lawn clippings. The leaf litter of trees and shrubs such as acacias and *allocasuarinas* that have nitrogen-fixing microbes associated with their roots (p. 119) typically contains about 2% nitrogen, so a mixture of it and eucalypt leaves is satisfactory.

A small amount of grit in the bed helps earthworms grind their food in their gizzards. Most manures and garden weeds will contain some grit. Ground limestone and crushed egg shells added to raise pH will often provide enough grit, but otherwise add a few per cent soil when using other 'cleaner' food.

Animal dung, lawn clippings, leaves and other bulk materials are usually scattered onto the surface of the bed under the covering material. Kitchen scraps are best buried in spots throughout the bed. Cabbage leaves and the bases of cauliflowers must first be chopped into small pieces. Citrus peels are quite acid. They should not make up more than a small proportion of the

food added at any one time. They should always be accompanied by a sprinkling of agricultural limestone, dolomite or wood ash. Meat scraps should be mixed with sawdust or other plant material.

Continue to add food to the bed until there is enough vermicompost to harvest. You can start removing some of the vermicompost after a few weeks. To obtain pure castings, you should stop adding food so that you force the earthworms to work over the bed materials for a couple of months.

MANAGEMENT

A well managed earthworm bed will have a pleasant earthy odour. Sourness or other unpleasant odours call for changes in management. Good management involves the following.

- Match food supply to the ability of the worms to use it. As a rough guide, 2 kg of worms need about 1 kg kitchen scraps or the equivalent per day. Two kg of earthworms will comprise about 2400 fat worms, 4000 breeders or 9000 'pitrun' (mixture of all sizes in a bed). Uneaten kitchen scraps will soon putrefy, souring the bed and creating unpleasant odours.
- Keep the bed at the right moisture content. Beds under cover will need to be sprinkled every 2–7 days, depending on the time of the year. Good drainage must be provided for outdoor beds.
- Good aeration of the bed is maintained by loosening it every couple of weeks with a fork of appropriate size. Be careful not to disturb the worms more than is necessary.
- Try with appropriate shading and insulation to keep the temperature of a bed in non-tropical areas in the range 12–25°C. That is not possible in some localities at some times of the year, but the nearer you get to this optimum, the faster will the worms grow and produce vermicompost.
- Check the pH of the bed from time to time. Try to keep the pH in the range 6–8. No pH adjustment should be necessary when the main food is manure from grass-fed animals. When the food is mainly kitchen scraps, it will be necessary to give a sprinkling of limestone and/or dolomite and/or wood ash and/or crushed egg shells from time to time.
- It may be necessary in some areas to prevent flies from breeding in the bed. A cover of fly screen should be enough.

SEPARATING WORMS FROM VERMICOMPOST

It takes about 6 months to produce vermicompost that is mostly castings.

One way of separating the earthworms from the vermicompost is to pile the contents of the bed into a cone on a solid surface in a brightly lit area. The worms will move down into the cone, so allowing you to repeatedly remove the top several centimetres of worm-free vermicompost. A small amount of hand sorting at the bottom of the cone will finish the job, or you can use this remaining mixture to seed a new bed.

Another way is to feed the worms down one end of the bed for a couple of weeks. Most of them will congregate around the food, making it easy to remove much of the vermicompost free from worms, but probably not cocoons.

SOME FACTS ABOUT VERMICOMPOST

Vermicompost has been described as the ‘most perfect plant food’, and as ‘much superior to the best garden compost’, and ‘the richest topsoil known to science for potted plants or for mulching the flower garden’. Is it that good? Let’s see.

PH

Microbial decomposition of plant materials, whether in a compost heap or inside earthworms, produces a compost which is near neutral in pH (typically pH 6.5–7). However, vermicomposts can be quite alkaline (one tested had a pH of 7.8) if large amounts of liming materials have been added to the culture bed. On the other hand, if the bed has been allowed to sour, the vermicompost produced can be quite acid.

You should check the pH of each new batch of vermicompost before using it on plants that might be harmed by very acid or very alkaline materials.

SALINITY

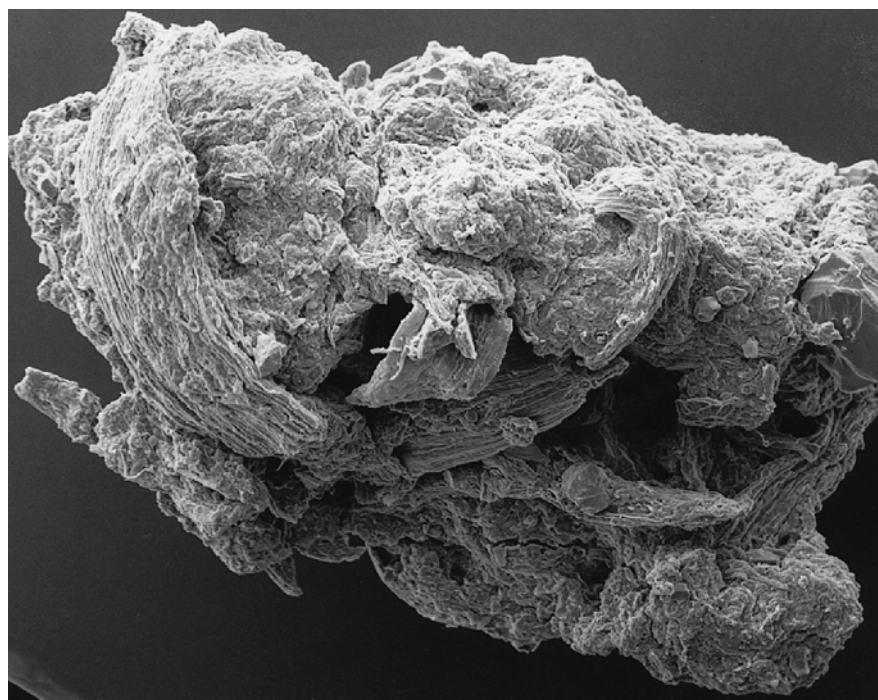
Some vermicomposts can be fairly saline because of the release of soluble nutrients during decomposition of feed and bedding materials. This salinity will rarely cause your garden plants any problems, but if you want to use vermicompost by itself as a medium in which to germinate seeds or grow

plants, you would be wise to remove some of the salts from the vermicompost before planting. Pour through the vermicompost a volume of water equal to about twice the volume of vermicompost; give a garden plant a boost by pouring the drainage water under it.

WEED SEEDS

Vermicomposts made from cow, sheep and horse manures and general garden wastes usually contain seeds from the plants eaten by these animals. Many seeds are either not eaten by earthworms or pass unharmed through their intestines.

The best way to get rid of most of the seeds is to first allow the manures to spend a week or two in a hot compost heap. You probably won't get rid of all of the seeds, but you will greatly reduce their numbers. An alternative during the summer is to solarise the materials before feeding them to the worms. See p. 40 for details.



Stewart McClure

Scanning electron microscope picture of an earthworm casting, showing the intimate mixing of mineral and organic materials.

PLANT HORMONES

Extravagant claims have been made for the beneficial effects of various vitamins and plant hormones contained in vermicomposts. The small amounts of these substances in vermicomposts might occasionally benefit some plants, but the concentrations are very variable and usually very low. Research has shown that you would be unwise to rely on your plants getting any benefit from any hormones in vermicompost.

PHYSICAL PROPERTIES

Well-made vermicompost has the rich black colour of humus, has a pleasant earthy smell and is granular in appearance. It is capable of holding a considerable amount of water. However, it can become hard to rewet if it is allowed to dry out. Wetting agents can aid rewetting. Rewetting problems are minimised if the vermicompost is used in mixtures with other materials.

CONCLUSION

Vermicomposts and worm castings are excellent materials for adding to your soil or potting mix, BUT they do not have magical properties. Just like other fertilisers and soil conditioners, they have their strengths and limitations. Vermicomposts are just one amongst many materials that will improve your soil and help your plants to grow.



5 Organic matter

You have made a large pile of beautiful compost, your worms have made a small mountain of vermicompost and your poultry have reduced your kitchen scraps to deep litter. What do you do now? How much of these materials do you need to add to your soil, and how should they be added?

Here are a few guidelines. Information about the good things that organic materials do to soils is given on pp. 104–111.

USING COMPOSTS AND VERMICOMPOSTS

Thoroughly matured compost has an earthy smell, has few recognisable pieces of the original organic materials and is a fairly uniform dark brown or black colour. Rain can leach nutrients from finished compost, so cover matured heaps until they are used.

Stored, moist compost will continue to decompose and so will become a richer and richer source of most plant nutrients. Dried compost will change little during storage.

Compost from hot heaps may be used around mature plants as soon as the temperature of the heap has come down below 40°C, say three weeks after building the heap. Leaving it to cure for a few more weeks will improve it by increasing its fineness and reducing its C/N ratio, so making it into a better source of nitrogen for plants. (Soluble nitrogen is released from compost only after its C/N ratio falls below about 25.) It will usually take 6–12 months to get useable compost from unturned heaps and bins.

Your soil and plants will get the most benefit from the compost if it is used before it has become uniformly very fine. In fact, a greater improvement in

soil structure is achieved with relatively fresh compost than with thoroughly matured compost.

MULCH OR DIG IN?

Sieved compost may be used as a top dressing for lawns, but only if you are sure that all weed seeds in it have been killed. Otherwise it may be either dug into garden beds for vegetables or flowers, spread as a mulch around shrubs and trees or spread between rows of growing plants. Rain or sprinkler water will wash nutrients from compost mulches into the soil and plant roots will grow up into the lower part of the mulch.

You can dig compost into the soil of a vegetable patch or a bed for annual flowers, if you have not converted your garden to no-dig. But if you have changed to no-dig, you have no choice but to spread the compost on the surface.

Try the following guidelines:

- Reserve your most highly matured compost for digging into garden beds for annual vegetables and flowering plants or for sprinkling around the plants as an alternative to more soluble fertilisers. A 5 cm layer should be ample.
- Organic gardeners might also make a surface application of similar compost between rows of vegetables part-way through a growing season. Apply a 2–4 cm layer.
- You can use less mature compost as a mulch under shrubs and trees. One



Rich compost ...



... by the barrow load ...



... is excellent for gardens.

application at establishment and one or two further applications in the first two years should bring the area up to self-maintenance through litter-fall. Each application could be of about 10 cm depth.

- Use relatively fresh compost for improving the structure of clay subsoils.
- Vermicompost and worm castings can be used at the same rate as 'ordinary' compost.

USING OTHER ORGANIC MATERIALS

Poultry manure is a very variable feast for your plants, as the nutrient content varies enormously between batches. The proportion of the nitrogen that is present in soluble form can range from zero to very high, depending on the age of the manure and processing. There is always some risk of burning plants through high salinity from poultry manure.

It is suggested that any one application of poultry manure should not be more than 300 g per square metre. You could repeat the application after a month or so, if your plants need more feeding.

Cow, sheep and zoo-animal manures can all be used at about the same rates as suggested for matured composts. Many bags of these manures and organic mulches carry no information about the nutrients in their contents. The high lime content of some will harm acid-loving plants. The sawdust and other low-nitrogen materials in some will not improve the growth of your plants. Labelling laws need to be extended to cover these materials.

Most products labelled as mushroom composts are the spent composts removed from mushroom farms after a mushroom crop has been harvested. The material contains both the compost and the 'casing' onto which the mushroom spore was sprinkled. Mushroom composts themselves are usually of neutral pH, but casings are usually very alkaline, so spent mushroom composts are generally alkaline. Their high soluble nutrient content often makes them very salty.

Do not use such composts if your soil is acid and you want to keep it that way.

Use them rather more sparingly than you would use 'ordinary' composts.

SOME FACTS ABOUT SOIL ORGANIC MATTER AND HUMUS

DEFINITIONS

Soil Organic Matter: Soil organic matter is all the plant and animal residues at various stages of decomposition, cells and tissues of soil organisms and substances formed by soil fauna and microbes found in or on the surface of a soil.

It includes (in our garden soil) bits of plant roots that have died, recognisable bits of leaves and twigs from the compost and green manure crops we may have dug in, bits of sawdust and feathers from the poultry litter we may have added before the last crop, the bodies of beetles, earthworms, grubs and bugs, the remains of hordes of bacteria, fungi and actinomycetes, and their spores, living members of all of these groups, multitudes of chemicals such as enzymes, amino-acids, antibiotics and ethylene that are either beneficial or harmful to microbes and plants, and last but by no means least, the complex organic molecules that are collectively called humus.

Humus: The more-or-less stable part of soil organic matter remaining from the decomposition of plant and animal remains. Humus is really a waste product produced by micro-organisms. It is dark-coloured and consists of large organic molecules containing mainly carbon, hydrogen and oxygen. These molecules are stabilised by aluminium. They also contain considerable amounts of nitrogen and sulphur and smaller amounts of other elements. Most humus is probably formed from lignin – the material that gives plant stems and wood their rigidity.

HOW MUCH ORGANIC MATTER DO SOILS CONTAIN?

Many Australian soils contain less than 1% organic matter. Few contain more than a few per cent.

The amount of organic matter in a soil depends on the following.

- The amount added from the plants growing on the soil, both from roots and litter from the tops. The more fertile the soil, the greater the return of organic matter.
- The amount added as compost, animal manures and the like.

- The clay content of the soil. With everything else being equal, a sandy soil will usually contain much less organic matter than a clay soil. In fact, it is difficult to maintain even a moderate amount of humus in a well-drained sandy soil. Humus forms very stable associations with clay particles. Much of it ends up sandwiched between clay particles, where it is protected from microbial attack. Increasing the clay content extends the protection to increasing amounts of organic matter, so adding both clay and organic matter to a very sandy soil will enable a much higher humus level to be maintained.
- Air supply, moisture and temperature. Soil microbes really zip along in a warm, moist, oxygen-rich soil that is also well stocked with their favourite foods. The irrigation water that you must use to keep your plants alive in hot weather also increases the rate of loss of the organic matter from the soil.
- How often you dig your soil. Digging speeds up the disappearance of soil organic matter. Digging always smashes some of the bonds holding organic matter and clay particles together. The organic matter is then exposed to attack by micro-organisms. So your soil loses some organic matter, but your plants gain from the nutrients released as the organic matter is decomposed.
- If you never add any organic matter to your soil, its content of organic matter could halve after about 25 years of annual digging.

THE GOOD THINGS ABOUT ORGANIC MATTER

Have you noticed that the large amounts of compost or animal manures that you add to your soil seem to disappear to almost nothing within a few months? Maybe you have wondered whether all the effort is really worth it. Why not just throw on some fertiliser from a bag? You can certainly supply nutrients that way, but you cannot buy good soil structure in a bag of chemical fertiliser.

Stick with your hard work. Your efforts to increase the humus content of your soil will be rewarded by better plant growth, better soil structure and therefore easier digging, or a decreased need to dig.

Here is a list of the good things that the organic matter in your soil does for your plants. But note that organic matter does not have 'magical' properties.

Plants and their products are no less healthy when grown in properly balanced hydroponic systems than in organic-rich soils.

Organic matter:

- Improves soil structure;
- Is a source of essential plant nutrients;
- Helps control plant diseases.

ORGANIC MATTER IMPROVES SOIL STRUCTURE

When we apply compost, poultry litter or a green manure crop to a soil there is a massive explosion in the population of microbes in it. These microbes (bacteria, fungi, etc.) produce sticky secretions and humus which bridge the gaps between mineral particles or groups of mineral particles and so bind them together into crumbs or aggregates.

This binding is at first rather flimsy and can be easily broken by cultivating the soil (p. 71). A year or two of leaving the soil undisturbed – as under a mulch – is necessary for loosely formed aggregates to be stabilised.

Typically, no more than 30% of organic materials added to a soil remains after a year. The rest has been used as food by countless hordes of micro-organisms and has ended up as carbon dioxide, water and nutrient elements that have been released into the soil.

It might take another year for soil microbes to eat half of the remaining organic matter. It is during this first couple of years that your plants will receive the most direct benefit from the added organic matter, mainly from the nutrients released into the soil around their roots.

As the years roll by, less and less of the remaining organic matter is able to be used by micro-organisms. Some of it is protected through being sandwiched between clay particles. Much of it is humus which, as it is a waste product of micro-organisms, is really not very good food for them.

But this long-lived humus is vital for the well-being of your soil and to future generations of plants that will grow in it. Humus is essential to good soil structure and the ability of your soil to provide air and water to the roots of your plants. The real value of humus is in its resistance to attack by microbes, rather than in its ability to release nutrient elements during attack.

Radiocarbon dating has shown that much of the humus of soils is very old. For example, one study showed an average age of 2560 years.

Because humus tends to remain in soil for as long as thousands of years, the plant nutrients in humus are only slowly made available to plants.

Some are released each year as microbes break down a small proportion of the humus: if the humus content of the soil is high, the decomposition of this small proportion can provide enough nutrients for good plant growth.

In other words, if your soil has a high humus content, you may be able to get good plant growth by using this 'capital'. But unless you return nutrients in recycled organic matter, your capital will eventually be reduced to such a low level that it will no longer be enough for good plant growth.

You will then be forced to rely on 'chemical' fertilisers for adequate nutrition. But without the return of organic matter, the structure of your soil will gradually deteriorate. Eventually the soil will be difficult to dig and your plants will grow poorly.

Humus is the vital ingredient that binds soil mineral particles into aggregates. If your soil has no humus, it will have no aggregates and therefore very poor structure. Poor soil structure means poor plant growth; it's as simple as that.

ORGANIC MATTER SUPPLIES NUTRIENTS

Composts, vermicomposts and animal manures contain plant nutrients in both readily soluble and slow-release forms. The soluble nutrients are quickly available to plant roots, while some of the others are slowly released as the organic matter is further broken down by soil animals and microbes.

The fertiliser value of a compost is directly related to the quality of the organic materials used to make the compost. Materials of low nutrient content give compost of low fertiliser value. Typical contents of dried compost are 1.4–3.5% nitrogen, 0.3–1.0% phosphorus and 0.4–2.0% potassium, with smaller amounts of other nutrients. Some composts are therefore relatively low in plant nutrients and good growth can only be achieved by supplementing them with manufactured fertilisers or organic fertilisers of higher nutrient content.

Nitrogen from organic matter

In most topsoils, about 95% of the nitrogen is present in the organic matter. Plants cannot get at it until it has been converted by micro-organisms to

ammonium or nitrate ions, that is, to an inorganic form. Microbial decomposition of organic materials therefore provides plants with a constant trickle of available nitrogen. Whether this trickle is enough for excellent plant growth depends on the amount of organic matter in the soil, its nitrogen content, and its rate of decomposition.

Most of the nitrate released by micro-organisms comes from organic materials added to, or formed in, the soil during the previous 1 to 5 years; only a small amount comes from (humus) materials that have been in the soil for more than 25 years. So the nitrogen in the very old humus fractions cannot be used by plants. (Cultivation increases the rate of release of nitrogen from these fractions but of course this cannot go on indefinitely.)



Compost is a mixture of humus, microbes and partly decomposed plant materials.

Repeated applications of organic matter with an adequate nitrogen level are therefore needed for good plant growth if we do not add nitrogenous fertilisers (which supply ammonium and/or nitrate). The annual amount of organic matter needed for a vegetable garden or bed for annual flowers is about a 5–10 cm layer of compost or about 300 g of poultry litter per square metre.

Nitrate is not held firmly in soils; it can easily be washed out by rain or sprinkler water. Organic matter, by providing a constant trickle of nitrate, reduces losses of nitrate compared with losses from similar amounts of nitrogen applied in a completely soluble fertiliser.

All of the nitrogen and sulphur in plant materials is lost to the air when they are burnt.

Over half of the nitrogen in organic residues that have been left on the surface of a soil may be lost to the atmosphere. This causes a dilemma for gardeners. Should the nitrogen be conserved by digging the residues into the soil, or should soil structure be conserved by scattering the compost on the surface? There is no right answer. Most gardeners will choose the easiest way of dealing with residues – minimal digging combined with mulching.

Phosphorus from organic matter

Soil organic matter may contain from 15–85% of the total soil phosphorus, yet in many soils plants have access to only a small proportion of this phosphorus. Plants take up phosphorus almost exclusively in the form of inorganic phosphate ions.

Most Australian soils are naturally deficient in phosphorus. Unless we correct this underlying deficiency with a concentrated source of phosphorus such as superphosphate, reactive rock phosphate or poultry manure, it is difficult to supply enough phosphorus to vegetable crops from composts only.

So, in new gardens, when digging-in organic materials or when making a compost heap, it is usually advisable to include a sprinkling of a concentrated phosphatic material such as superphosphate. But please note the caution on pp. 143 and 153 about adding too much phosphorus.

Potassium, calcium and magnesium from organic matter

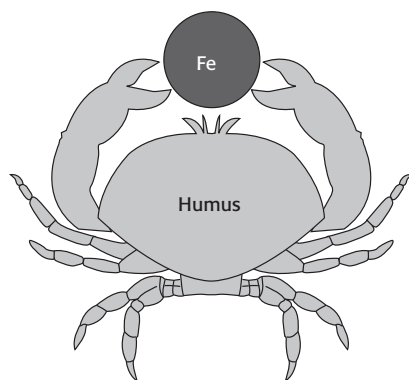
Decomposing plant residues are excellent sources of potassium, calcium and magnesium in forms that are readily available to plants.

Almost any dead plant material will provide some potassium, calcium and magnesium, but legumes (as for example in clover and lucerne hays) and poultry manure are particularly rich sources. The potassium of organic materials is easily dissolved in water, so such materials as cow manure, compost and seagrasses that have been sitting out in the rain for more than a month contain little potassium.

Trace elements from organic matter

Another way in which soil organic matter regulates and improves nutrient supply to plants is through its ability to 'chelate' some trace elements.

'Chelation' (pronounced kee-lation) refers to the ability of some organic molecules to hold atoms of such metals as iron, copper, manganese and zinc in a claw-like grip. (Chelate comes from the Greek word *chele* = claw.) Chelates of metals are readily available to plants. Chelation protects these metals from ending up in the soil in forms that are very insoluble and so of low availability to plant roots.



'Chelation' of trace elements.

Organic matter usually improves the supply of iron to plants but there is one situation in which this may not be so. Large quantities of carbon dioxide are produced in soils after green manure crops have been dug in. In alkaline (calcareous) soils some of this carbon dioxide is converted to bicarbonate. Bicarbonate interferes with the availability of iron to some plants, so green manuring of alkaline soils can produce iron chlorosis (yellowing of young leaves) in plants that are particularly susceptible. Allowing a few weeks between digging in a cover crop and planting the next crop should prevent this problem.

HUMUS REGULATES THE SUPPLY OF NUTRIENTS

As well as releasing nutrients to plants as it is decomposed by microbes, humus also regulates their supply. The surface of humus is like a sponge: it holds nutrients so that water does not as readily wash them out of the reach of plant roots; it holds the nutrients until plant roots are able to help themselves to them as they are needed. More detail on this is given on p. 63.

DISEASE CONTROL WITH ORGANIC MATTER

There is a general belief among organic gardeners that many diseases of plants can be prevented or eliminated through the addition of organic matter to soils. There is much truth in this but it is by no means universally true.

Sometimes organic matter reduces the severity of or prevents the establishment of a disease; sometimes, in seemingly similar situations, organic matter has little effect on a disease or can occasionally make it worse.

To get some understanding of these variable effects of organic matter, we need to know something about the complexities of life amongst the micro-organisms and small animals in soils, because it is micro-organisms and small animals that produce many of the changes in plant growth that we call disease.

Fungi, actinomycetes, bacteria, viruses and small animals such as nematodes are the organisms we need to know about. In any soil there are usually many thousands of different species of these organisms present. They interact with one another, with soil components and with plants in complex ways.

It is important to realise that most soil organisms are not harmful to plants. Most are either neutral or beneficial to plants. Many soil organisms live only on dead organic matter. They decompose the remains of plants and animals in soils and so recycle to plants the nutrient elements in that organic matter. Some soil organisms live only on other organisms while others can live on

both dead materials and living organisms. These kinds of organisms therefore can be very useful to plants if they suppress populations of organisms that are able to attack plants.

Soil organisms that are able to attack plants are called pathogens (from the Greek: path = disease or suffering; gene = start or beginning).

Even though a soil may contain many pathogens, it does not necessarily follow that plants will be attacked or that an attack will seriously damage or destroy the plants. The ability of a pathogen to infect a plant depends on the numbers of infectious organisms present, their vigour, environmental conditions (including the numbers and types of other organisms present) and the susceptibility of the plant (that is, on its ability to defend itself).

Adding organic matter to a soil adds food for microbes in that soil as well as the extra microbes present in the organic matter. If the organic matter contains a balanced supply of nutrient elements – and especially if there is an ample supply of nitrogen and phosphorus – there is a population explosion in the soil as the microbes feast on the new food supply. This explosion is mainly amongst those microbes that can easily feed on dead organic matter and on other microbes. Pathogenic microbes – those that need a living plant as food – miss out. They are therefore surrounded by increasing numbers of other microbes, some of which are able to attack them.

The weapons used in the attack include the same antibiotics that we use to control infectious diseases, enzymes that dissolve holes in the outer walls of the cells of the attacked, suffocation as the attacking microbes use the oxygen around them, and starvation as they use all the available food. Organic matter can therefore reduce the incidence of disease in plants through its effects of soil microbes. All this activity also rapidly decomposes pesticide residues.

Organic matter may also reduce plant disease by other means. Well-fed plants have all their internal mechanisms for resisting disease working at full efficiency; starved plants, like starved human beings, are more susceptible to attack. Organic matter supplies plants with an abundant and well-balanced supply of nutrients, so it promotes plant vigour and hence their ability to resist pathogens. The better physical properties of a soil that usually result from the addition of organic matter will also promote better root growth and hence greater plant vigour.

Yet another way that some of the micro-organisms present in actively decomposing organic matter can help plants is through their production of various chemicals such as salicylic acid (as in aspirin). These chemicals are

able to strengthen plants' immune systems so that they are better able to resist attack by pathogens.

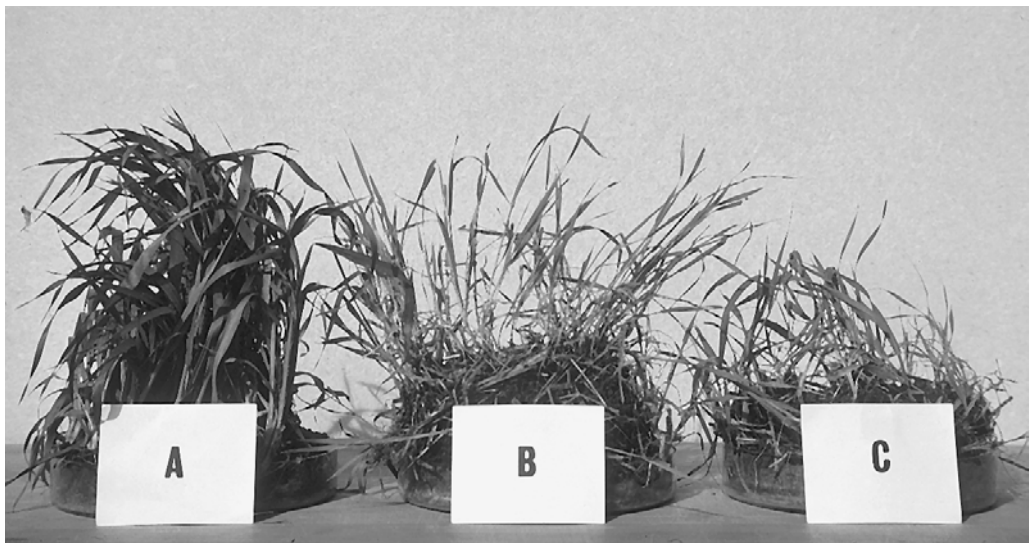
Organic matter does not always decrease disease in plants. Sometimes it has no effect; sometimes it increases disease. The reasons for this are sometimes obvious but often not. If we introduce pathogens along with the organic matter we add to our soil, we hardly give our plants a chance. For example, digging in dead tomato plants into soil intended for more tomatoes is especially likely to lead to disease problems.

POSSIBLE PROBLEMS WITH ORGANIC MATTER

While organic matter is almost always beneficial to soils and plants, there are a few situations in which it can cause problems.

Plants can have problems with organic matter if it:

- Contains toxins;
- Contains pathogens;
- Robs the plants of soluble nitrogen;
- Prevents the soil from rewetting after drying.



Reduced wheat growth (B and C) caused by residues of the previous crop decomposing in the soil.

TOXINS FROM ORGANIC MATTER

Some soil organic matter is able to injure plants, or even kill them. These are lumped together under the term phytotoxins, which literally means plant poisons. Phytotoxins are organic chemicals that come partly from plant residues newly dug into the sod and partly from microbes as they decompose residues.

For example, considerable amounts of toxins can be produced if fresh plant residues are dug into the soil. Roots of seedlings planted into this soil can be damaged if they come into contact with these toxins. At best, their growth can be reduced for a while; at worst, they are killed.

Such damage is prevented if the toxin-producing phase of decomposition is allowed to take place in a compost heap. All of the toxins will have been destroyed by the time the compost is ready for use.

If you do want to dig plant residues (including hay and straw) into soil, you should wait for about 5 weeks before planting. The wait can be reduced to about 3 weeks when green manure crops are dug in.

INTRODUCTION OF PATHOGENS

You are asking for trouble if you add severely diseased plant materials to your soil. It is better that you lose the organic matter by dumping the materials into the garbage bin rather than run the risk of a massive infection next season. The only safe way of using diseased materials is by running them through a compost



Poor growth (right) caused by the incorporation of sawdust into the soil.

heap that remains at above 55°C for 3 days. The pathogens are unlikely to be killed in a compost bin or in a heap that does not heat much above 40°C.

NITROGEN DEFICIENCY

Plants can suffer from nitrogen deficiency if you dig into the soil under them any organic matter such as sawdust that has a high C/N ratio, that is, too little nitrogen in it in relation to its carbon content. Soil microbes use most of the soluble nitrogen in the soil as they decompose the sawdust, leaving little for plants growing there. If you do want to use sawdust as a source of soil organic matter, you should first add to it some urea (about 2 kg/m³) or poultry manure (about 30 kg/m³) and then either compost it or age it for a year or so.

NON-WETTING SOILS

Many very sandy soils are naturally water-repellent (p. 72). Other sandy soils can become water repellent following the addition to them of large amounts of organic matter. Water can sit for hours in pools on the surface of the dry soil.

Difficulty in wetting is caused by the presence of waxy materials on the surfaces of sand particles. These waxy materials are produced mainly by fungi as they decompose organic matter.

IMPROVING WETTABILITY

One way of improving the wettability of a non-wetting soil is for you to stand out in the rain or under the sprinkler and ‘thump’ the soil so that you force water into close contact with soil particles. Once wet, the soil will be easy to rewet as long as it does not dry out completely. But thumping will again be necessary if it dries out. Better ways of improving wettability include:

- Adding clay: Non-wetting of sandy soils can usually be permanently cured by increasing their clay content to above about 10%. That means adding 10–15 kg of clay per square metre and mixing it with the top 10 cm of sand.
- Using wetting agents: The simplest way of ensuring quick rewetting of dry sandy soils is through the use of wetting agents.

A wetting agent is really just a special type of detergent that is only slowly biodegraded and that is not toxic to plants at the recommended rate of use. The wetting agent allows water to spread more easily across the surfaces of

particles in a soil or potting mix, in much the same way that dishwashing detergent allows water to spread over and stick to a greasy plate.

Despite what advertisements state, wetting agents are usually needed only on sandy soils. They are unlikely to improve wetting or water use efficiency on heavier soils.

APPLYING WETTING AGENTS TO SANDY SOILS

1. Use a fork to make small holes in the soil.
2. Apply wetting agent as recommended, typically at 5 mL per square metre. You must dilute the concentrated wetting agent so that the 5 mL is carried in about 2 litres of water. Thus, 25 mL of wetting agent in 10 litres of water will treat 5 square metres of soil.
3. Encourage penetration of the solution by further forking, if necessary.
4. Irrigate at a low rate (5–10 mm per hour) so that water can penetrate deeply into the soil.



6 Understanding fertilisers

DEFINITIONS

A *fertiliser* is anything that we add to a soil or other growing medium that will supply one or more of the nutrients essential for the growth and health of plants.

To *fertilise* is to make productive.

A *fertile soil* is one that is capable of providing everything that plants need for vigorous, healthy growth. That includes more than ample supplies of nutrients: it includes excellent structure so that roots grow easily.

Organic fertilisers are the remains of plants and animals. The main organic fertilisers are compost, leaf mould, ground bones, dried blood and seaweed, and manures from horses, cows, poultry, pigeons, pigs, bats and seabirds (guano) and humans.

Commonly used naturally occurring *mineral fertilisers* include gypsum, limestone, dolomite, rock phosphate, sulphur and some crushed rocks.

Other *mineral fertilisers* include waste mineral materials such as wood ash, the ash from some coal-fired power stations, blast furnace slags and flue dust from cement works.

Every garden centre has on sale a wide range of manufactured '*chemical*' *fertilisers*. We meet them in bags, packets and bottles, in mixtures put together for lawns, roses, fruit trees, etc.

ORGANIC AND 'CHEMICAL'

Every reader of this book will have come across statements to the effect that it is unnatural and damaging to our plants and to us to use manufactured

‘chemical’ fertilisers. Those who say this advocate the sole use of natural organic and mineral fertilisers such as those listed above. This is the organic gardening approach.

Organic gardeners and farmers also prefer not to use manufactured pesticides (fungicides, insecticides, herbicides), believing them to be harmful to soil micro-organisms, food crops and us.

This section will not be concerned with pesticides, but with the relative merits of organic and ‘chemical’ methods of feeding plants.

ALL FERTILISERS ARE ‘CHEMICAL’

Plants take up nutrients from the growing medium around their roots in the form of ions (such as nitrate, ammonium, phosphate, potassium, and so on). These ions are the same, no matter whether they have come from a ‘chemical’ fertiliser or an organic fertiliser. So as far as their content of immediately soluble major nutrients is concerned, organic and ‘chemical’ fertilisers are both ‘chemical’.

It is in the percentage of total nutrients that are immediately soluble in water that the two types of fertilisers differ most. Except for some of the phosphorus and sulphur, the nutrients in most ‘chemical’ fertilisers are completely soluble in water. Only a portion of the nutrients in organic fertilisers is immediately soluble in water.

Because ‘chemical’ fertilisers are soluble, and generally have much higher concentrations of nitrogen, phosphorus and potassium, they are added at much lower rates than are organic fertilisers. One of the most common problems associated with the use of ‘chemical’ fertilisers is that if too much is applied and/or if they are not washed into the soil with enough water, plants and soil animals can be damaged by a too-high concentration of soluble nutrients (high salinity). They are not damaged if these fertilisers are added at the correct rate (see p. 138), and are thoroughly watered in.

A high proportion of the nutrients in so-called ‘hot’ organic fertilisers such as pure pigeon manure is also quickly soluble. Damage to plants is just as likely with these as with ‘chemical’ fertilisers, if they are applied at too high a rate. For example, seedlings can be burnt by the ammonia given off by fresh poultry manure sprinkled amongst them, if it is not quickly watered into the soil.

Repeated heavy applications of poultry and pigeon manures will add to a soil excessively high amounts of phosphorus that can produce an imbalance in

just the same way as repeated applications of superphosphate might. Don't believe all the claims made in advertisements for organic fertilisers. *Judge what is being said by the facts given here.*

A MAJOR BENEFIT FROM ORGANIC FERTILISERS

A major benefit to soils and plants provided by organic fertilisers comes from their organic matter content. As well as being a slow-release fertiliser, this organic matter improves soil structure. This benefit should, by itself, be enough to encourage all gardeners to recycle organic matter back to their soils. Disease control (p. 109) and nutrients are an important bonus.

GETTING THE BEST FROM BOTH 'CHEMICAL' AND ORGANIC FERTILISERS

Both 'chemical' and organic fertilisers have a place in every garden. You should never feel guilty about using a manufactured fertiliser just because someone has decreed that such fertilisers are 'unnatural', and therefore harmful to soils and plants. The actual nutrient elements are no different when they are present in 'natural' or 'chemical' fertilisers. Overuse of natural fertilisers such as poultry manure damages soils and plants just as surely as overuse of a 'chemical' fertiliser. Damage is avoided when we understand the strengths and weaknesses of each type of fertiliser. We must learn to use them in ways that give our plants a balanced supply of all the nutrients they need.

Organic and chemical fertilisers can complement one another. For example, the amount of humus produced from organic 'wastes' is often limited by the amount of nitrogen present. Adding a modest amount of nitrogenous fertiliser to a compost heap will allow greater production of humus. More humus will be produced from organic mulches if you include in them urea or ammonium sulphate at a rate of 10–20 g per square metre of soil surface. Also, the production of organic matter for your garden will be boosted if you overcome deficiencies with 'chemical' fertilisers.

BACKGROUND TO PLANT NUTRIENTS

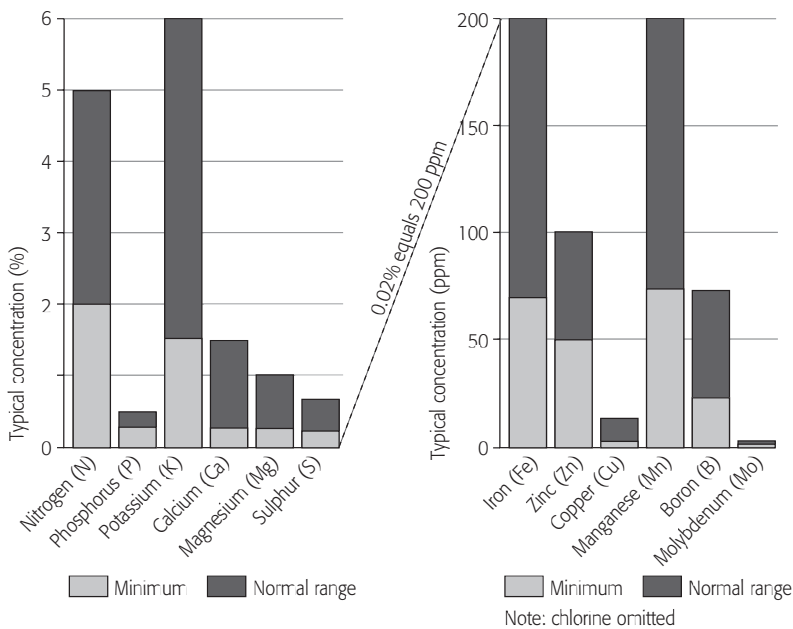
Plants need balanced amounts of at least sixteen elements. Of these, three – carbon (C), hydrogen (H) and oxygen (O) – come from the carbon dioxide of the air, and water. A supply of them is assured as long as fresh air circulates around plants, and water is provided.

The other nutrient elements come mostly from the water and solids of the growing medium, be it soil, potting mix or hydroponics solution. These elements can be divided between two groups according to whether they are needed in large or small amounts (see below).

Several other elements are beneficial to at least some plants. These elements are aluminium, sodium, cobalt, vanadium and silicon. (The blue pigment of hydrangea flowers contains aluminium. Sodium is a micronutrient for C4 (subtropical and tropical) plants. Cobalt is essential to *Rhizobium* bacteria and vanadium to blue-green algae. Silicon markedly improves the growth of rice and sugar cane in some soils and helps protect many plants from fungal diseases.)

Plant growth is poor if only one of the nutrient elements is in short supply, even though there may be ample supplies of all the others (p. 121). Any deficiency in the growing medium must be made good through the use of fertilisers or other materials that contain the needed nutrient(s).

On the other hand, too much of any one of these elements, and some others such as aluminium (Al), arsenic (As), bromine (Br) and fluorine (F), can cause toxicity symptoms in plants and will reduce their growth.



Major nutrient elements (needed in largest amounts) found in dried leaves.

Trace, minor or micro-nutrients (needed in only tiny amounts) found in dried leaves.

The following information about these nutrient elements will help you to get the most out of fertilisers.

THE MAJOR NUTRIENT ELEMENTS

Nitrogen (N)

Nitrogen is a key element in amino acids (the building blocks of proteins), in the genetic coding material of chromosomes and in many other important compounds in plants. For vigorous growth, plants need a steady supply throughout the growing season (p.122).

Plants might well lament 'nitrogen, nitrogen everywhere, and not a molecule that we can use'. They are surrounded by air that is 78% nitrogen, but they cannot use this nitrogen to make protein without the help of micro-organisms (see below), or factories that convert atmospheric nitrogen into fertilisers such as urea and ammonium sulphate.

Plants that provide their own nitrogen

There are two groups of plants that provide their own nitrogen (with the help of some micro-organisms).

The larger of the two groups is the pea family (*legumes*). All of these plants form bean-like pods. Most have pea-shaped flowers: the main exceptions are acacias and calliandras. The roots of plants of the pea family have nodules that have been formed by a kind of controlled invasion by *Rhizobium* bacteria (p. 122). The bacteria live inside the nodules. The plant provides the bacteria with sugars; the bacteria use the sugars as energy to convert nitrogen gas from the atmosphere into various nitrogen compounds that can be used by the plant.

Commonly grown pea-family plants are the peas and beans of the vegetable garden and the clover and medics of pastures.

Frequently grown ornamentals include species from the genera: *Acacia* (p. 123), *Albizia*, *Bauhinia*, *Bossiaea*, *Brownia*, *Calliandra*, *Cassia*, *Ceratonia* (carob), *Crotalaria*, *Cytisus*, *Daviesia*, *Erythrina*, *Eutaxia*, *Gleditsia*, *Hardenbergia*, *Indigofera*, *Kennedia*, *Laburnum*, *Leucaena*, *Lotus*, *Mimosa*, *Pultenaea*, *Robinia*, *Tamarindus* and *Wisteria*.

The smaller group of nitrogen-providers contains species of the genera *Casuarina*, *Allocasuarina* and *Alnus*. Micro-organisms called *Frankia* form associations with the roots of these trees (p. 122).

Most soils have populations of free-living bacteria with names such as *Clostridium*, *Azotobacter* and *Methanobacillus* which are also able to fix nitrogen.

Other microbes that fix nitrogen include the blue-green algae (p. 123). When they are not causing problems by growing prolifically in waters polluted with phosphates, they are busily fixing nitrogen for plants in warm, moist soils.

Phosphorus (P)

Phosphorus is essential to virtually every process taking place in plants (p. 124). To describe here its role in any detail is impossible; it helps in the transfer of energy from sunlight to the plant and in providing the energy for many of the chemical reactions involved in growth and reproduction.

Potassium (K = Kalium)

Potassium is an important part of the salts in the 'juices' of plants and is involved in the processes regulating the extension of stems (p.124). Potassium plays a major role in protecting plants from disease. It does this in part by promoting the development of thick outer walls in the outer cells of plants. Potassium deficiency leads to the accumulation of sugars and nitrate in plant tissues and it is these that provide much of the food for attacking organisms.

Sulphur (S)

Sulphur is a constituent of many flavour and odour compounds in plants – the aroma of onions, cabbages, brussel sprouts etc., the odour associated with urine after eating asparagus and the stench of rotting seaweed.

More importantly, sulphur is a constituent of the essential amino acids cysteine and methionine, which are part of the genetic coding materials and proteins of all living things.

Calcium (Ca)

Plants need calcium for normal cell division, as a component of cell walls, as a component of the salts inside cells and as part of the genetic coding materials (p. 124). Calcium is vital for root growth.

Magnesium (Mg)

Magnesium is a key component of the chlorophylls, the green colouring materials of plants. It is therefore vital to photosynthesis (p. 2).



A shortage of just one nutrient will reduce plant growth. Here the three *Phlox drummondii* 'Candy' plants (B, C and D) received less sulphate-sulphur than did (E). Plant (A) received no sulphur.



Top: Nitrogen deficient *Philadelphus mexicanus* (Mock Orange) plants are a paler green than those well supplied with nitrogen. **Bottom left:** Nodules formed by *Rhizobium* bacteria on legume roots. **Bottom right:** Nodule clusters formed by *Frankia* on the roots of a *Casuarina*.

John Cappel

Paul Redell



Acacias give a bright splash of colour when they are in flower, but they quietly provide nearby plants with nitrogen throughout the year.



PD Baker and E. A. WS (SA)

The nitrogen-fixing blue-green alga *Anabaena spiroides*, magnified 800 times.



Phosphorus deficiency in tomato.



Severe potassium deficiency is common in palms growing in sandy soils.



Calcium deficiency in *Petunia*.



Acute iron deficiency in *Petunia* (right) and normal growth (left).



Manganese deficiency in lettuce.



Copper deficiency in *Chrysanthemum*.



Allen Gilbert

Whiptail in cauliflowers is caused by a lack of molybdenum. It is most likely to be found in very acid, sandy soils.



David Nichols

Ammonium toxicity symptoms in *Impatiens*.



Phosphorus toxicity symptoms in *Acacia* seedlings.



Salvia seedlings easily succumb to iron toxicity if the pH of the growing medium is too low and iron is being supplied in chelated form.



Copper toxicity in silver beet.



Healthy stocks (right) and a plant suffering from zinc toxicity (left).



Amongst garden plants, pansies and violas are the most susceptible to boron toxicity.



Cymbidium orchid severely damaged by fluoride emissions from a brick works.



Damage caused by a herbicide.



Iresine leaves damaged by hormone residues contained in horse manure.

David Nichols/Dabco Pty Ltd

TRACE ELEMENTS

Iron (Fe =Ferrum)

Iron is a constituent of many plant compounds that regulate and promote growth. It is especially important to the functioning of chloroplasts – the green parts of plant cells that contain chlorophyll and are the ‘factories’ of photosynthesis (p. 125).

Manganese (Mn)

Manganese is essential to the functioning of key enzymes (p. 125). It has a major function in photosynthesis.

Copper (Cu)

Copper is an essential constituent of a number of compounds called enzymes that are involved in many complex life processes in plants (p. 125).

Zinc (Zn)

The major role of zinc in plants is in the production of auxins, which are plant hormones which help control stem elongation, leaf expansion and the formation of roots.

Boron (B)

Boron is needed for the formation of cell walls in rapidly growing tissues. Boron deficiency reduces the uptake of calcium and inhibits the plant’s ability to use it.

Molybdenum (Mo)

Molybdenum is needed for the conversion of nitrogen gas from the air to soluble nitrogen compounds by bacteria and other soil organisms that fix nitrogen (p. 125). Legumes, therefore, have a special need for molybdenum over and above the needs for their own growth processes. Molybdenum is also essential to the formation of proteins from soluble nitrogen compounds.

READING THE SIGNS

There are people who believe that our lives are written in our palms. Palmistry might help some people, but ‘leafistry’ has much more to offer gardeners. Leaves can tell us a great deal about the health of a plant, if only we will take the time to look. Here are some clues to interpreting what we might see.

DEFICIENCY SYMPTOMS

In the early stages of deficiency, or in mild deficiencies, the only sign of the deficiency is somewhat retarded growth. This is difficult to pick up without a nearby well-fed plant for comparison. Analysis of leaves from the plant can sometimes pinpoint the deficiency, but this course of action is not often open to home gardeners.

More severe deficiencies announce their presence by the plant's leaves developing off-colours or distortions that are characteristic for each deficiency, and that vary somewhat from species to species. Multiple deficiencies greatly complicate the symptoms. Other causes of leaf symptoms include herbicides, hormones contained in manures from intensively raised animals and fluoride toxicity.

The following information should help you in determining the cause of poor growth and off colours if these are due to a nutrient deficiency.

Nutrient deficiencies in plants – a quick guide

• Symptoms appear first in the OLDEST leaves

Nitrogen – general yellowing, often with reddening; stunting; leaf drop; premature maturity (p. 122)

Magnesium – patchy yellowing between veins; strong reddening, especially around edge of yellow zones; leaf remains green in a wedge at the point of attachment

Potassium – scorched margins; spots surrounded by pale zones; younger leaves may show red pigmentation (p. 124).

Phosphorus – poor growth; erect habit; lack-lustre look; blue-green, purple colours (p. 124).

Molybdenum – mottling over whole leaf; cupping of leaves and distortion of stems (p. 125)

Cobalt – legumes only, as for nitrogen

• Symptoms may appear first in either the OLDEST or YOUNGEST leaves, but often first in the MIDDLE leaves

Manganese – interveinal yellowing; veins pale green, diffuse; water-soaked spots, worst in dull weather (p. 125)

• Symptoms appear first in the YOUNGEST leaves

Calcium – tiphooking, blackening and death (p. 124)

Sulphur – yellowing, usually of whole plant; leaves small with rolled down edges; some pigmentation (p. 121)

Iron – yellowing between the veins, which remain sharply green; youngest leaves almost white if severe (p. 65)

Copper – death of tips; yellowing of leaves; distorted young growth; severe decrease in flowering (p. 125)

Zinc – small leaves; bunching of young leaves; yellow-white mottling (p. 65)

Boron – margins chlorotic (yellow); crumpling; blackening; distortion; death of growing tips

Toxicity symptoms

Nitrogen – Too much of ammonium-nitrogen can cause death of roots, wilting of shoots, dead spots in leaves, especially in young plants (p. 126). Too much total nitrogen gives dark green, succulent leaves which are prone to disease. It may also induce deficiencies of calcium and zinc.

Phosphorus – Death of leaf margins, then the whole of the oldest leaves, of some native Australian and other species. The youngest leaves of some species become yellow through interference with iron supply by the excess phosphorus. The most easily affected species come from the family Proteaceae, but some *Acacia* are also affected (p. 126).

Potassium – Too much potassium may produce magnesium deficiency.

Sulphur (*Rare*) – Early death of old leaves, similar to that caused by nitrogen deficiency.

Calcium (*Rare*) – Too much calcium in proportion to the magnesium or potassium present in the growing medium can produce magnesium or potassium deficiency.

Magnesium (*Rare*) – Too much magnesium in proportion to the calcium present in the growing medium can produce calcium deficiency symptoms.

Iron (*Rare*) – Restricted to such plants as rice growing in waterlogged soils that contain too little silicon, and to plants growing in potting mixes in which the main source of iron is synthetic iron chelates (p. 126).

Manganese – Leaf margins of older leaves show brown spots surrounded by yellow zones; sometimes, iron deficiency symptoms.

Copper – Stunting and symptoms of iron deficiency (p. 126).

Zinc – Stunting, iron deficiency symptoms (p. 127).

Boron – Margins of the oldest leaves turn yellow, then scorch to a dark brown to black (p. 127).

Aluminium – Poor root growth; stunting of shoots, with colours similar to those of phosphorus deficiency.

Arsenic – Wilting of new leaves, stunting, sometimes burned reddish spots in older leaves, and death.

Bromine, chloride and sodium – Brown margins and tips of the oldest leaves, spreading until leaves drop.

Fluoride – Death of tips and margins of the leaves, especially in grasses and other plants with long narrow leaves (the monocots). Gladioli and grapevines are especially sensitive to fluoride (p. 128).

Note that herbicides (p. 128) and hormone residues (p. 128) can also cause symptoms in plant leaves.

- *Toxicity caused by high salinity is discussed in Chapter 9.*

Nutrient content of some fertilisers

Figures are % of the nutrient element in the dried material, except as indicated.

Fertiliser	N	P	K	Other nutrients	
Natural Organic Fertilisers					
Composts					
Garden	1.4–3.5	0.3–1	0.4–2	all organic fertilisers contain all other nutrient elements in low to moderate concentrations	
Spent mushroom	0.4–2.2	0.1–0.6	0.3–1.5		
Municipal solid wastes	0.7–1	0.1–0.4	0.3–0.4		
Sewage sludge (Biosolids)	2–6	0.5–6	0.2–0.7		
Vermicompost	1.1–4	0.3–3.5	0.2–2.1		
Animal manures					
Sheep	1–3	0.1–0.6	0.3–1.5		
Cow	0.2–2.7	0.1–1	0.06–2.1		
Pig	0.5–2	0.3	0.5		
Horse	0.7–2	0.3	0.6–1.2		
Poultry					
–deep litter	1–3	0.25–1.6	0.8–2.4		
–battery hen	3–7	1.5–2.5	0.8–3		
–pelleted	3–4	1.3–3.6	1.2–2		
Pigeon	1.5–8	1–3	1–3		
Other plant materials					
Seaweed/seagrasses	0.5–1.5	0.1–0.2	0.1–1.9		
Lucerne hay	2.2	0.3	1–2		
Meadow hay	1.1	0.2	1.5		
Bran	2	1	1.1		
Tea leaves	3–4	0.1	0.2		
Animal byproducts					
Blood and bone	4.5–6	5–7	0–2		
Bone meal	3	9	0.4		
Hoof and horn	11–13	0.3	–		
Fish wastes	4–9	1–4	0.8–1		
Feathers	8–12	–	–		
Urine (human) (g/L)	10	1	1.3		

Liquid manure – see table on p. 150

Nutrient content of some fertilisers (continued)

Figures are % of the nutrient element in the dried material, except as indicated.

Fertiliser	N	P	K	Other nutrients
Manufactured organic fertilisers				
Urea	46			
Urea formaldehyde	38			
IBDU (isobutylidene diurea)	31			
Natural mineral fertilisers				
Calcium carbonate (limestone)				40 Ca
Dolomite				22 Ca, 13 Mg
Gypsum				23 Ca, 19 S
Potassium chloride			52	
Rock phosphate		13–14		17 Ca
Sulphur				100 S
(Zeolite)			0.2	1.7 Ca
Granite dust			3.5	
Basalt dust			1.5–3	
Waste mineral materials				
Wood ash		0.6	1–8	
Flue dust			up to 18	
Manufactured fertilisers				
Ammonium nitrate	35			
Ammonium phosphates	12–21	23–26		
Ammonium sulphate	21			24 S
Calcium nitrate	12			7 Ca
Iron sulphate				20 Fe, 11 S
Magnesium sulphate				10 Mg, 13 S
Potassium sulphate			45	18 S
Potassium nitrate	13.8		39	
Potassium phosphates		18–23	29–45	
Superphosphate, Single		9		21 Ca, 11 S
Triple		20		24 Ca

Mixtures

Many different combinations of the above, with compositions as shown on their labels.

NOTES ON ORGANIC FERTILISERS

All organic fertilisers contain the full range of plant nutrients, but concentrations vary greatly. The concentrations of nutrients in moist organic fertilisers will be lower than the ranges quoted in the table by amounts that depend on the wetness of the fertiliser.

Some seagrass mulches have a high lime content and very high boron contents. They can cause very long term problems for some plants, notably roses.

Animal manures contain weed seeds, unless these have been killed by heat or through fumigation.

Use with caution poultry manure that smells strongly of ammonia. If you do scatter it amongst plants, you must immediately water it into the soil, otherwise the plants may be burnt.

Poultry manure can be quite alkaline, because of the shellgrit eaten by the birds. Check its pH before you add it to a soil that you want to remain acid. If you do use it, you must monitor soil pH.

Some composts can be quite alkaline because of lime added to the heap. Check them too if you want your soil to remain acid.

The relatively high concentrations of potassium in hay and straw means that repeated removal of these materials from farms with light (sandy) soils eventually leads to potassium deficiency 'down on the farm' while your garden is enriched.

Blood-and-bone and related organic fertilisers provide a continuous supply of nitrogen and phosphorus over many months. Mixtures of superphosphate and blood-and-bone provide both rapidly available and more slowly available phosphorus from the one application.

The lack of potassium in some formulations of blood-and-bone can be corrected by adding 80 g potassium sulphate to each kg of blood-and-bone.

In soils of neutral to slightly alkaline pH, the phosphorus of bone meal is more readily available than is the phosphorus of rock phosphate.

Human urine should be diluted with 10 volumes of water before it is used as a fertiliser.

There are now many organic mulches on the market. Most are not registered as fertilisers, although they may have some fertiliser value. Quality (nutrient

content) varies widely. With a general absence of analytical information on most packages, it is difficult to choose which is best for a particular purpose.

For example, while seaweed and genuine seaweed composts will have perhaps 2% potassium, some preparations made from sea grasses washed up on beaches and long exposed to rain have less than one-tenth of this concentration. It is best to assess a new product (through use on a small area) before general application throughout your garden.

NOTES ON OTHER FERTILISERS

Ureaformaldehyde and IBDU are slow-release sources of nitrogen (only).

Potassium chloride (Muriate of Potash) is completely soluble in water.

Wood ash and flue dust have about one half the liming ability of limestone.

The small amounts of nutrients in basalt and granite rock dusts can only become available to plants as the dusts are 'weathered'. That takes many years, so they are usually of little use for overcoming a severe deficiency of, say, potassium. Their weathering is speeded up in compost heaps.

Note that dusts prepared from many secondary rocks (mudstones, sandstones, shales) have very little nutritional value.



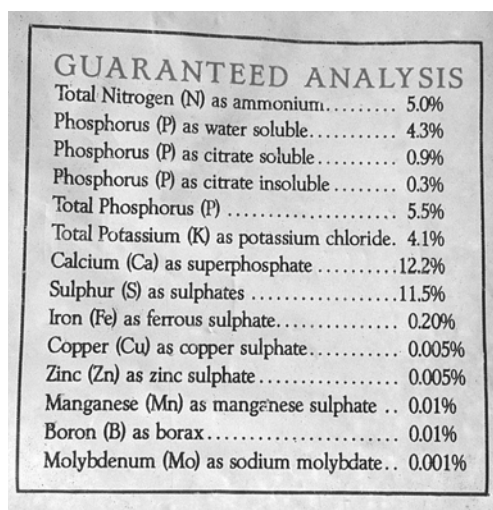
IBDU releases nitrogen a little more rapidly than does urea formaldehyde.

LABELS ON FERTILISER PACKAGES

Labels on fertiliser packages sometimes confuse users. Labels list only nutrient elements; they leave out the oxygen, chlorine and water associated with these elements, so the listed percentages never add up to 100%. This is not cheating, but simply a result of the shorthand used. For example, potassium sulphate (written K_2SO_4 by chemists) contains 45% potassium (K) and 18.4% sulphur (S). The remaining 36.6% is the oxygen combined with the sulphur.

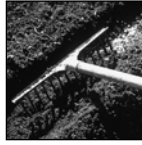
Here are the meanings of a few common entries on labels.

- **Nitrogen:** The nitrogen content is usually listed as coming from ammonium, urea, nitrate or organic matter. All forms except the organic are completely and rapidly soluble in water. High proportions of the total nitrogen present in forms other than nitrate will mean that the fertiliser will acidify a soil or potting mix.
- **Phosphorus:** The total phosphorus content is usually listed under the headings water soluble (completely and rapidly soluble in water), citrate soluble (not as soluble in water, but can become available to plants in time), citrate insoluble (usually considered to be unavailable to plants).
- **Potassium** will be listed as being added as potassium sulphate (old name: sulphate of potash), potassium chloride (old name: muriate of potash) or a potassium phosphate. Those gardeners whose water is salty (containing much chloride) and those who grow plants in pots will try to avoid using fertilisers containing chloride.
- Some imported fertilisers have their contents of phosphorus and potassium given as phosphoric acid (P_2O_5) and potash (K_2O), respectively. This archaic notation has long been obsolete in Australia. To get the percentages of P and K, multiply the P_2O_5 and K_2O percentages by 0.44 and 0.83 respectively. For example, a mixture that is said to contain 19% potash contains $19 \times 0.83 = 15.8\%$ potassium.



GUARANTEED ANALYSIS	
Total Nitrogen (N) as ammonium.....	5.0%
Phosphorus (P) as water soluble.....	4.3%
Phosphorus (P) as citrate soluble.....	0.9%
Phosphorus (P) as citrate insoluble.....	0.3%
Total Phosphorus (P)	5.5%
Total Potassium (K) as potassium chloride.	4.1%
Calcium (Ca) as superphosphate	12.2%
Sulphur (S) as sulphates	11.5%
Iron (Fe) as ferrous sulphate.....	0.20%
Copper (Cu) as copper sulphate.....	0.005%
Zinc (Zn) as zinc sulphate	0.005%
Manganese (Mn) as manganese sulphate ..	0.01%
Boron (B) as borax.....	0.01%
Molybdenum (Mo) as sodium molybdate..	0.001%

Typical label on a package of garden fertiliser.



7 Using fertilisers

FERTILISERS FOR NEW GARDENS

The first step in the successful establishment of a new garden is to have the soil analysed. It will cost about \$100 (2000 price). The Yellow Pages for your area will list laboratories that provide this service. Ask for analysis for pH, salinity, available phosphorus, trace elements and exchangeable cations. Follow the laboratory's sampling instructions. Make sure that the laboratory provides as part of the fee a recommendation on what fertilisers you should apply.

Whether you do or do not have the soil analysed, you may find the following guidelines helpful.

FIRST, USE MINERAL FERTILISERS AS NEEDED:

- Use a ground limestone-dolomite mixture (1:1) to bring the pH of acid soils into the range you require (see p. 55).
- Apply gypsum to improve the structure of clay soils (p. 26) and to supply soluble (sulphate) sulphur to sandy soils.
- Apply agricultural sulphur to acidify soils that are slightly acid to slightly alkaline (pH 6 to 8), if the plants to be grown require this.
- At the same time, add as much compost to the soil as you can afford.
- Also, add concentrated fertilisers to overcome specific deficiencies:
- A severe deficiency of phosphorus is most easily overcome through application of single superphosphate at a rate of about 60 g per square metre.

Such an application is probably only necessary when establishing a garden on soil that has never been farmed or that is little more than deep subsoil.

- If you do want to use reactive phosphate rock to overcome phosphorus deficiency, you will need to use it at about three times the rate recommended above for superphosphate to get the same effect. Reactive phosphate rock is an effective source of phosphorus only on fairly acid soils (pH less than about 5.5).
- These additions of phosphorus, and indeed the application of any organic fertiliser containing more than about 1% P, may not be needed or could be damaging if you want to grow plants that are intolerant of even modest amounts of phosphorus (pp. 150–1).
- A severe potassium deficiency (likely only in very sandy soils) is best overcome through an initial application of potassium sulphate at 15–30 g per square metre, watered in thoroughly. Long-term improvement in potassium supply in very sandy soils can be achieved through the addition of clay (see p. 24).
- You probably won't need to bother about additions of trace elements if you have added ample amounts of manures and composts to the soil.
- Rapid establishment of trees and shrubs is aided by scattering a couple of tablespoons of controlled-release fertiliser in the bottom of each planting hole.

HOW MUCH CONCENTRATED FERTILISER CAN I ADD IN AN APPLICATION?

The more concentrated the fertiliser, the smaller the amount that can be added at any one time.

The table gives a guide for vegetables.

In contrast, a typical compost containing about 1% N (moist compost), and with much of this N in slowly available form, could be applied at several kg per square metre. Poultry manure, whether loose or in pelleted form, perhaps containing 2–4% N, should be applied at no more than about 300 g per square metre.

% N in the fertiliser	Max. rate of application (g/m ²)
5	180
7	130
10	90
13	70
16	60

FERTILISERS FOR MAINTAINING PLANT GROWTH

Once you have overcome any severe deficiencies and have built up the organic matter content of your soil, you will have come to a maintenance situation. Here are guidelines for different areas of your garden. Lawns are covered in Chapter 10.

FERTILISERS FOR ORNAMENTAL TREES AND SHRUBS

No fertiliser is needed if:

- your soil has had large amounts of organic matter from a wide variety of sources added to it over the years, or
- fertiliser was applied generously during establishment, and
- the leaf litter is left to remain as a mulch, and
- the trees and shrubs are growing well.

The growth of non-leguminous shrubs and trees is improved when they form part of mixed plantings with legumes. The extra growth is due to their use of some of the nitrogen fixed by the *Rhizobium* bacteria associated with the roots of the legumes (see p. 119).

You will probably need some fertiliser for successful establishment of exotic (non-Australian) trees and shrubs. Dig plenty of organic matter into the soil before planting. Use a couple of tablespoons of slow-release fertiliser in the bottom of the planting hole for early feeding. Scatter a general garden fertiliser (NPK ratio of about 8:4:7) on the soil surface during the first growing season after establishment. A higher rate of fertiliser application will be needed if little organic matter has been used, or if the organic matter is of low nitrogen content (p. 132).

Annual applications of fertiliser may be needed for plants that flower heavily and/or that have to be pruned back each year. Roses and hydrangeas are commonly grown examples.

FERTILISERS FOR FRUIT TREES

You will no doubt want to have the shortest possible time between planting a fruit tree and picking the first fruit from it. The time-to-first-pick can be minimised by applying ample amounts of fertiliser to the young tree, so that it rapidly forms a large framework.

At planting:

- Remove all weeds and lawn to at least one metre from where the tree is to be planted.
- Mix generous amounts of rich organic matter into the soil out to a metre all around where the new tree is to be planted,
- Add a plant 'pill' or a tablespoon of a controlled-release fertiliser to the soil in the bottom of the planting hole.
- Mulch the area of bare soil around the tree.

YOUNG TREES

Continue to remove all weeds and lawn over an increasingly large area around the tree.

- Apply about 200g of NPK fertiliser (about 10%N, 2%P, 7%K) in the first year, then at a rate of 300 g for each year of growth, up to a maximum of 3 kg per tree.
- Split the application: apply two-thirds in early spring and one-third in early autumn in southern Australia.
- The application can be split into four for tropical trees, and applied during the main growing season.
- It is absolutely essential that you thoroughly wet the soil before applying fertilisers, and then thoroughly water the fertiliser into the soil.

MATURE TREES

- Allow leaf litter to remain as a mulch and source of recycled nutrients.
- For mature trees, there is no need to exceed about 3 kg of the fertiliser per tree. Apply half in spring and half after harvest. Cut the total amount if growth is excessive. You can use a nitrogen-only fertiliser such as ammonium sulphate or urea for mature trees growing in soil that contains ample amounts of phosphorus and potassium from past applications.

FERTILISERS FOR VEGETABLES AND BEDDING PLANTS

Most vegetables and bedding plants have been bred to grow rapidly and to yield prolifically. They can do this only if they receive ample amounts of all nutrients. The amount and type of fertiliser needed depends on the amounts applied previously and on the amount of organic matter you add.

SOUTHERN AUSTRALIA, SANDY AND LOAM SOILS

1. *Little organic matter used*

- For all vegetable crops, other than peas and beans, an NPK mixture with an 8:4:9 composition (approximate) should be used at planting.
- For crops on soils that already have a large bank of phosphorus, use an NPK mixture with a lower P content. Fertilisers formulated for lawns have a low P content and are ideal for all plants on soils that already have a large bank of P.
- The actual amount to use, again assuming that organic matter is not being used, will be about 60 g per metre of row, preferably placed in a band below and to the side of the seedlings or seeds.
- Root crops such as carrots and turnips will probably need only one side dressing during the growing season, but leafy crops – cabbage, lettuce, spinach, cauliflowers – may benefit from two.
- Peas, beans and other legumes only need an initial dressing of something like a 5:5:4 mixture at about 100 g per square metre and no side dressings later.



Fertiliser for vegetables is best placed in the bottom of the planting furrow ...



... and covered with soil before ...



... the seed is sown.

2. Considerable applications of organic matter

Be guided by growth. Fertiliser applications will be lower than when little organic matter is being used.

- Root crops may need a light application of potassium sulphate (10–15 g per square metre).
- Leafy vegetables may need some extra nitrogen.
- Peas and beans will probably grow well without extra fertiliser.

SOUTHERN AUSTRALIA, HEAVIER SOILS

- Many heavy soils need larger amounts of phosphorus than do soils of lighter texture. If generous past applications of superphosphate, reactive rock phosphate or pigeon and poultry manures have not been made, you will need to add these in addition to a regular mixed fertiliser.
- For all vegetable crops, an NPK mixture with a 5:6:4 composition (approximate) should be used at planting, at 60 g per metre of row.
- Leafy vegetables will probably benefit from one or two side dressings of urea or ammonium sulphate, or some other high-nitrogen fertiliser.

NORTHERN AUSTRALIA

The same basic recommendations given for southern Australia can be used in northern Australia, except that more N and (sometimes) K must be applied in additional side dressings. Leafy vegetables need extra nitrogen and the root crops (and bananas) extra potassium.

FURTHER NOTES ABOUT FERTILISERS FOR VEGETABLES

Here are some notes that will help you decide whether or not you need to apply fertiliser to your vegetable garden.

More nitrogen?

- If you can grow large and tight heads of cabbage, broccoli or other green, leafy vegetables, your soil is able to supply an ample amount of nitrogen for any crop. Even if you do need extra nitrogen for these leafy crops, there may be enough available nitrogen in the soil for most other plants.

- Your soil probably has enough nitrogen if it has received large amounts of rich compost and/or animal manures in the previous couple of years. These release soluble nitrogen to plants as they are slowly decomposed by soil microbes.
- Therefore, if you can each year apply a 6–8 cm layer of thoroughly rotted compost to your vegetable patch or bed for bedding plants, you will probably not need any other fertiliser.
- Extra nitrogen can be supplied via an NPK mixture (see table on p. 138 for rates), urea (10 g per square metre, maximum), ammonium sulphate (20 g per square metre, maximum) or blood-and-bone (40 g per square metre).

More phosphorus?

- If you can grow vigorously healthy tomatoes, celery and capsicum, your soil has plenty of phosphorus. Testing will not give you a better answer.
- There is probably plenty of phosphorus if there have been heavy past applications of poultry manure and/or fertilisers containing phosphorus.
- Even though they may have started off with too little phosphorus, many garden soils eventually come to contain large amounts. Adding more will not improve plant growth, and it might even decrease it through interference with trace element supply. If you know that your soil contains an ample supply of phosphorus, you should apply nitrogen only, or nitrogen and potassium.

The following are nitrogen-plus-potassium fertilisers that you can easily make yourself

- Ammonium sulphate/potassium sulphate 3:1 by weight (16% N, 11% K, to be used at no more than 60 g per square metre)
- Urea/potassium sulphate 1: 1 by weight (23% N, 22% K, to be used at no more than 35 g per square metre).

More potassium?

- If you can grow excellent beetroot, carrots, sweet corn, celery, tomatoes and capsicum, your soil has plenty of potassium.
- Other vegetables needing ample amounts of potassium include cabbage, cucumber and potato.

- Rockmelons, rhubarb, bananas and pineapple all need heavy applications of potassium to grow vigorously. By way of illustration, the potassium concentration in banana leaves is 2.5 times their nitrogen content.
- The minerals of clay soils or heavy loams can usually provide ample supplies of potassium.
- Heavy past applications of wood ash, poultry manure, granite dust and fertilisers containing potassium will have added to the store of potassium in the soil.
- Adding large extra amounts of potassium to soils that already grow excellent plants may produce magnesium deficiency in your plants.

Potassium and sandy soils

Sandy soils have little ability to supply potassium and to hold that which is applied (p. 177).

To improve the long-term supply of potassium in sandy soils:

- Add clay. For each square metre of surface, add 20–30 litres of clay soil and dig it in to a depth of about 20 cm, or;
- Add very finely ground basalt (preferable) or granite dust. Add 1–2 kg per square metre and dig in. Dusts of these rocks are slow-release sources of potassium.

For a quick overcoming of potassium deficiency:

- Add a soluble source of potassium. Potassium chloride, potassium sulphate (15–30 g per square metre), or an NPK mixture (double these rates) are the easiest to obtain. Wood ash can also be used (about 200 g per square metre), as long as its alkalinity is acceptable.
- Potassium sulphate is the preferred source of potassium in areas where soils and water supplies are rather saline. The extra chloride in potassium chloride (and in mixtures containing it) can be quite harmful to plants in these areas.

Note that rain washes much of the potassium from manures, composts, seaweeds and seagrasses that have been left out in the open, and so greatly reduces their value as fertilisers.

More sulphur?

- Soils that have received ample amounts of organic matter will usually have plenty of sulphur, and in slow-release form.
- The cheapest source of extra sulphur is gypsum (calcium sulphate). Add 200–300 g per square metre every year to sandy soils. Coarse (sandy) grades of gypsum last longer than fine grades.

More calcium and magnesium?

- If you can grow vigorous, prolific sweet corn, your soil is not short of magnesium.
- You can ignore these nutrients if the pH of your soil is 6 or above and you have not been adding excessive amounts of potassium.
- When raising soil pH, use dolomite or a 1:1 mixture of ground limestone and dolomite, so that you add both calcium and magnesium. Ground limestone alone does not supply much magnesium.
- To supply more magnesium to plants in a soil that you do not want to become less acid, use magnesium sulphate (Epsom salts) at 100 g per square metre and water it in thoroughly.

More trace elements?

Gardeners often ask: How do I know whether my soil/potting mix has enough of each of the trace elements? A related question is: Should I regularly use a fertiliser that contains trace elements? Here are some answers for soils. Answers for potting mixes are given on p. 259.

- If you have been adding considerable amounts of organic matter (compost, manures) to your soil, it is almost certain that it will have ample amounts of every trace element. An exception to this general statement is that if at the same time your soil has become alkaline, the availability of the trace elements might be too low for some plants.
- Even if you haven't, the minerals of most soils are able to supply ample amounts of all trace elements.
- Generally, therefore, it is not necessary to repeatedly use fertilisers containing trace elements. A definite deficiency is best cured as shown below.

Iron

- Plants whose natural habitat had very acid soils probably won't be able to get enough iron from calcareous (alkaline) soils. The tell-tale sign of deficiency is to be seen in the youngest leaves. Mild deficiency shows as pale patches between the veins (p. 130). In severe iron deficiency the young leaves are totally yellow or white.
- Even if your soil was once acid, over-use of lime, repeated use of alkaline water, application of over-limed compost (including spent mushroom compost) or mulches containing lime, can produce iron deficiency – the so called 'lime-induced chlorosis'. Adding too much phosphorus can also interfere with iron supply to plants.
- A quick and easy check of whether yellowing of young leaves is due to iron deficiency is to spray the plant with an iron chelate (pronounced kee-late). Greening within a week indicates iron deficiency, and a need to take more permanent action than spraying with iron chelate.
- The benefit of one spraying will last no longer than a few weeks. Drenching an alkaline soil with iron sulphate or chelate is useless. The pH of slightly alkaline or neutral soils can be lowered as shown on p. 57. The box gives a treatment that will be effective for many plants on all but the most alkaline soils.
- Note, however, that some acid-loving plants that are particularly susceptible to lime-induced chlorosis can only be successfully grown in very acid soils (pH 5.5 or lower). Here is a list of species with the highest susceptibility. Note that some selections (varieties) within each species will be more tolerant of high soil pH than others.

'Iron compost'

Use this technique (p. 177) as a sure-fire way of long-term prevention and cure of lime-induced chlorosis in ornamental shrubs and trees.

Take some compost, peatmoss or animal manure. Moisten it until you can just about squeeze water out of it.

To each 10 litres add one cup (about 230 g) of iron sulphate.

Mix thoroughly.

Dig holes about 20 cm deep into the root zone of the plants to be treated. A normal garden spade can be used for making holes under larger shrubs, but a trowel, crowbar or small auger should be used under smaller shrubs. Three holes would be suitable for a rose bush, perhaps 6–8 for a large *Camellia*, *Grevillea* or *Banksia*.

Compact the iron-rich organic matter into each of the holes.

Water the plant.

The plant's roots will soon be growing in the organic matter and taking up the iron, free from interference from the surrounding soil.

One treatment should remain effective for several years, unless your irrigation water has a high total alkalinity.

Abelia, avocado, azalea, blueberry, *Callistemon*, *Camellia*, citrus, *Dichondra*, *Gardenia*, *Hibiscus*, honeysuckle, *Hydrangea*, juniper, lilac, *Liquidamber*, *Magnolia*, *Nandina*, peony, *Photinia*, *Pyracantha*, privet, raspberry, *Rhododendron*, rose, strawberry, *Verbena*, *Viburnum*, *Wisteria*.

- Some types of plants that normally cannot be grown on calcareous soils can be grown after they have been grafted onto rootstocks that tolerate these soils. Roses and citrus are available on such rootstocks.
- Lawns on alkaline soils and in the tropics during the 'wet' often respond to an application of iron. Spray the grass with a solution containing 3 g per litre iron sulphate. Leave the solution on the leaves.

Manganese

- Some highly calcareous soils may also not be able to supply enough manganese. If spraying with an iron chelate does not cure yellowing, you can suspect manganese deficiency. Spray the affected plants with a solution containing 2 g manganese sulphate per litre. Even if this does green the plant, the effect will be temporary. And as in the case of iron, adding manganese sulphate to the soil will not be effective for long. You could make a manganese-rich compost, but usually it is best to grow only those plants that tolerate your alkaline soil.

Zinc and Copper

- Citrus growing on neutral and alkaline soils often show mild yellowing of leaves due to zinc deficiency. The symptoms are made worse by application of nitrogenous fertiliser. The symptoms are reduced by spraying once or twice each spring-summer with a solution containing 10 g zinc sulphate per litre. Dissolve the zinc sulphate, then add 5 g of builder's lime per litre. Shake during use to keep the lime in suspension.
- Except for zinc in citrus, deficiencies of copper and zinc are rare in urban areas because of the widespread use of copper (pipes, sprays) and zinc (galvanising, dust from tyres). Fertilisers and 'manufactured' soils containing biosolids (sewage sludge) will supply large amounts of copper and zinc.

Boron

- If you can grow excellent beetroot, cauliflowers, celery, grapes, swedes and turnips, your soil is not deficient in boron.

- Boron deficiency is unlikely except in areas where very acid, sandy soils have been limed (as on the Southern Tablelands of NSW). Boron deficiency is also common in some palms in some soils in the wet tropics. Applying 1.2 g borax (NO MORE) per square metre will overcome deficiency.

Molybdenum

- If you can grow excellent beans, peas and cauliflowers, your soil has plenty of molybdenum. Any sign of 'whiptail' in cauliflowers is readily overcome with an application of 0.35 g sodium molybdate per square metre. Raising the pH of a very acid soil (by adding liming materials – see p. 56) often eliminates molybdenum deficiency.

Toxicities (of copper, zinc, boron, manganese and aluminium) are likely only in very acid soils – those with pH values below 5 – and then not in all soils. Raising soil pH will overcome most toxicities.

FOLIAR FEEDING

Q. I have heard that plants can absorb fertiliser solution through their leaves. When should I use a foliar feed?

- A. Not often. Foliar feeding is a rather inefficient and time-consuming way of feeding plants. Often, much of the benefit comes from the fertiliser that reaches the soil in runoff from the leaves. Providing an adequate supply of nutrients in the soil (or potting mix) itself is the most efficient way of feeding most plants. There are, however, several situations in which feeding a plant through its leaves is worthwhile.

If you do want to feed your plants through their leaves, note that high humidity aids uptake. Therefore, spray in the late afternoon or early evening, unless the particular plants are easily attacked by mildew. Then you should spray early in the morning. Wet both upper and lower leaf surfaces. The nutrients enter through the leaf cuticle, mainly in the area around stomata.

- Iron, zinc and manganese can be put directly into the leaves of plants growing on alkaline soils, as was described on pp. 146–147.
- In cold areas, early spring growth can be stimulated by a spray containing 0.5–1% urea (5–10 g per litre of water).

- Sometimes, newly transplanted seedlings may benefit from a foliar spray of NPK fertiliser. Any benefit will usually be smaller for seedlings from cellpacks (there is little damage to roots during transplanting) than for those from community punnets, from which individual plants must be torn with much damage to roots.
- You can quickly get some nitrogen into a starved plant by spraying it with a solution containing 5–10 g urea and 1 mL of leaf wetter (dishwashing detergent will do) per litre.
- Plants growing in situations where any fertiliser applied to the soil will be quickly stolen by the roots of other, more aggressive, plants growing nearby can be fed successfully through their leaves.

Generally, it is best, and safest, to supply the major nutrients to plants through their roots.

MAKING YOUR OWN ORGANIC LIQUID MANURE

If you don't mind the smell, you can make a liquid manure by soaking manures and composts in water. Soak one volume of manure or compost in 10 volumes of water for 10–14 days. The composition of this liquid manure is quite unpredictable, as is shown by the examples in the table.

A liquid manure can also be made from immature compost. Soak one volume of compost in five volumes of constantly oxygenated water for 14 days. These 'compost teas' and extracts of animal manures and spent mushroom compost have many beneficial effects on plants that inorganic fertilisers do not have. The microbes, humus and other organic compounds they contain have hormonal effects on plants; they help the plant protect itself against attack by pathogens on both its roots and leaves. Regular spraying with fresh compost tea can virtually eliminate mildews and other fungal diseases of the leaves of some plants. See for yourself!



The requirements for making liquid manure.

Composition of some liquid manures

One volume of manure was shaken for one day with 10 volumes of water.
The concentrations are mg/L of nutrient in filtered extracts.

Nutrient mg/L in the liquid	MANURE				
	Cow	Poultry	Poultry pellets	Pigeon	Worm castings
Nitrate–N	0!	310	0!	0!	77
Ammonium–N	0	15	180	110	15
Phosphorus	13	59	24	67	19
Potassium	210	560	810	610	150
Sulphur	41	25	190	250	20
Calcium	10	70	32	34	31
Magnesium	4	64	24	34	31
(Sodium)	52	95	120	170	40
Boron	0.06	0.3	0.36	0.5	0.1
Copper	0.04	0.2	0.8	2.4	0.01
Iron	1	0.2	3	6.5	0.2
Manganese	0.04	0.2	0.2	0.2	0.04
Molybdenum	0.01	0.04	0.2	0.2	0.0
Zinc	0.1	0.1	0.9	1.4	0.02
pH	9.0~	7.3	7.9~	7.9~	6.5
EC** (dS/m)	0.7	2.6	4.7*	3.4*	0.9

! Extracts of other samples did contain soluble nitrogen ~ May harm acid-loving plants. * Should be diluted 1:1 before use. ** EC = electrical conductivity, a measure of salinity. See Chapter 9.

THE SPECIAL NEEDS OF AUSTRALIAN NATIVE PLANTS

The many hundreds of Australian native plants grown in gardens come from a wide range of soil types and climatic zones. They can therefore have very different fertiliser requirements. Here are a few guidelines.

Many species in proteaceous genera such as *Banksia*, *Telopea* (waratah), *Grevillea*, *Isopogon*, *Dryandra*, *Hakea*, etc., and southern African genera such

as *Protea* and *Leucadendron*, are especially efficient at extracting phosphorus from soils (p. 178). Application of a phosphatic fertiliser to sandy soils in which proteaceous species (and some species from other genera) are to be grown is a sure way of killing them through phosphorus toxicity and/or iron deficiency.

Non-proteaceous genera known to contain species that are prone to phosphorus toxicity include *Acacia*, *Baeckea*, *Bauera*, *Beaufortia*, *Boronia*, *Bossiaea*, *Brachysema*, *Chorozema*, *Daviesia*, *Eutaxia*, *Hypocalymma*, *Jacksonia*, *Lechenaultia* and *Pultenea*.

Many other Australian native plants are also quite efficient at extracting phosphorus from soils that have very low amounts of available phosphorus. They thrive in disturbed roadsides soils that would not allow any growth from many exotic plants. Yet many of these plants do grow more rapidly (and perhaps therefore have shorter lives) when NPK fertiliser or organic fertilisers are applied during the first year. If you do apply fertilisers to them, use no more than half the rates suggested for vegetables.

GREEN MANURE CROPS

A green manure crop is a crop that is grown to be dug into the soil just as the plants start to flower. The idea is that the organic matter so provided improves soil structure. Legumes will provide extra nitrogen to the soil. Their growth can protect what would otherwise be bare soil. But note:

- Your soil is tied up while the green manure crop is growing.
- Digging in the large tops of tick beans, lupins and the like is hard work.
- The roots of plants you put into the soil within 5 weeks of digging-in the green manure crop may be damaged by toxins temporarily produced as the residues decompose.
- Only a tiny amount of humus is supplied by a green manure crop, because the succulent green material contains little lignin.
- By all means grow a green manure crop if the alternative is that the soil remains bare, but it might be best to compost the crop rather than dig it into the soil.

In theory, green manure crops are a GOOD THING. In practice, they are of limited use. An excellent vegetable patch is possible without green manuring.

ANSWERS TO COMMON QUESTIONS ABOUT FERTILISERS

Q. Should I use a solid fertiliser that is not completely soluble, a soluble powder or a liquid?

A. All three types of fertiliser are useful. The solids are much cheaper per unit of fertiliser than are the liquids. The first type of solid fertiliser is the first choice for general garden use. Soluble powders can be used to produce a liquid fertiliser for giving individual plants a boost. The (more expensive) liquids are best reserved for use with pot plants.

Q. Plastic-coated controlled (slow) release fertilisers are expensive. Do they have any special merits for use on garden soils?

A. They may be a bit expensive for general garden use, but for time-short people their ability to supply long term from one application makes them economical, especially for plants in containers. For gardens, the best slow-release fertiliser is soil humus. In sandy soils and soils lacking in humus, manufactured controlled-release fertilisers can be useful in providing a steady trickle of nutrients instead of the feast and famine of soluble fertilisers. Losses of nutrients in drainage waters are usually less from controlled-release fertilisers than from soluble fertilisers.

Q. The water that I use on my garden is very alkaline. Which is the best type of fertiliser to use to counteract this alkalinity?

A. If the pH of your soil is being increased by the alkaline water, and you do not want it to increase, you need to use acidifying fertilisers, particularly ammonium sulphate. You will need to apply agricultural sulphur as well if soil pH continues to rise (p. 57). Always check soil pH before taking any of these actions.

Q. Different fertilisers have different proportions of ammonium and nitrate–nitrogen. In which situations should I use the different formulations?

A. Use those containing high proportions of ammonium and urea when you want to reduce soil pH or at least not have it rise. Use those with at least 50% of their nitrogen as nitrate when you do not want your soil to become more acid. Information about ammonium and nitrate is given on the label.

Q. Is there any danger in repeatedly using just the one type of fertiliser?

A. Yes, there is some danger, but for most fertilisers it is fairly small. It is necessary to maintain a balance between the different nutrients. This is easiest when you use ample amounts of compost. The acidity produced

through repeated use of urea and ammonium-based fertilisers may require balancing with lime. Repeated applications of high-phosphorus fertilisers (including poultry manures) are to be avoided once there is enough phosphorus in a soil.

Approximate cost of different types of fertilisers

Given as cents per gram of nitrogen.

Solid garden fertilisers	0.5–6
Powders	4–21
Controlled-release	5–10
Liquids	14–79

Q. How can I boost the concentration of one of the nutrient elements in a bought fertiliser?

- A. Add urea or ammonium sulphate to boost nitrogen. A 1:1 mixture of urea (46% N) and a fertiliser containing 10% N will have 28% N $((10+46)/2)$. A 1:1 mixture with ammonium sulphate will contain 15% N.

Add superphosphate (9% P) to boost phosphorus. A 1:1 mixture with a fertiliser containing 5% P will have 7.5% P.

Add potassium sulphate (45% K) to boost potassium. A 1:1 mixture with a fertiliser containing 9% K will have 27.5% K.

Q. Should I leave the fertiliser on the surface or dig it into the soil?

- A. Never dig in fertilisers applied to perennial plants, trees and shrubs. Their roots will be damaged by the digging. Scatter the fertiliser powder onto the mulch under the canopy of the plant being fertilised. Water thoroughly (apply about 10 mm – see p. 167).

Place soluble fertilisers in a band below or to the side of seeds being planted, NEVER along with the seed.

Well rotted organic fertilisers can be dug into soils for vegetables and annual plants or used as a mulch around them. More can be applied as a surface mulch around established plants.

Q. How far from the plants should I apply fertiliser?

- A. Anywhere under a plant's canopy, except immediately up against their stems and trunks. The roots of mature trees extend well beyond their canopies, so they often poach nutrients from other parts of the garden.

Q. How can I prevent the fertiliser from damaging ('burning') my plants?

- A. Soils must be thoroughly watered before and after applying side dressings of soluble fertilisers to growing plants.

Do not apply soluble fertilisers at more than the rates recommended on p. 138.



8 Water

GETTING THE MOST OUT OF RAIN

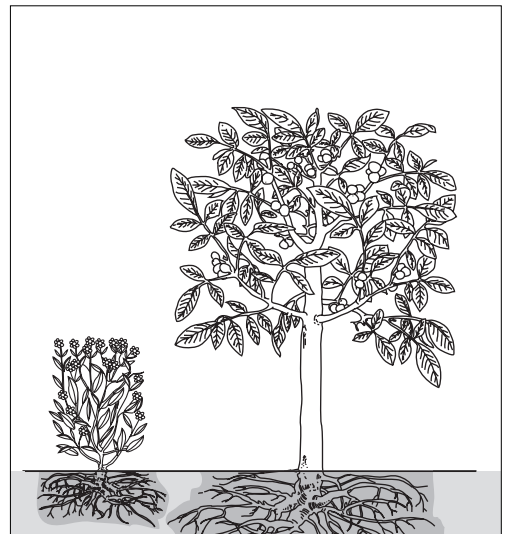
Australia is a land of extremes. One part of the country can be too wet at the same time as another is too dry. A few hours of rain can turn a drought into a flood. There are not many times in a year when rain provides just the right amount of water for plants. Sometimes we must deal with excess water, as is discussed on p. 176. More often, we must make sure that as much as possible of the water that rain brings soaks into our soil. Here is how to do it, but first, here is an essential mental picture.

THE SOIL AS A RESERVOIR

Think of the top half metre of your soil as a large reservoir of water. It is filled by prolonged rain or irrigation. It is emptied mainly by plants, but also by losing water through its leaky bottom and by evaporation from its surface.

Deciding when to water is easiest if we know how big the reservoir is and how quickly water is removed from it.

To get an idea of reservoir size, we need first to understand what happens between water and soil particles.



Your soil is a large reservoir which you need to fill with water from time to time in dry weather.

If we turn a cup of water upside down, all of the water runs out – pulled out by the force of gravity. The top part of a soil is a bit like an upside down cup: it doesn't have a solid bottom to it. Why is it that all of the water in it doesn't just run out into the deep subsoil?

The answer is that soil particles and water usually like to stick together; water is attracted to the surfaces of soil particles and is held fairly firmly by them.

This attraction can be seen if you touch a small clod of dry soil to water sitting on a plate: the water is rapidly pulled – soaks – into the soil (p. 179). Attraction can also be seen when we stand a pot of dry garden soil in a shallow tray of water. The surface of the soil will be wet within a few hours because of the attraction between soil particles and water.

This upward pull on water is the reason why water does not simply run straight through a soil. The downward pull of gravity is balanced by attraction between water and soil particles. The total 'amount' of attraction per cubic metre of soil will be greatest for soils with the greatest total particle surface area. That means that clay soils, with their small particles and therefore large surface area, have a greater total 'pull' on water than will the same amount of a sandy soil. Clay soils have many very narrow pores and these can hold large amounts of water. Sandy soils have relatively much larger pores and these hold smaller amounts of water.

The table on p. 160 gives a rough idea of the amounts of water that can be held in soils of different textures.

GETTING WATER INTO SOILS

Most of the water that plants need is taken from the soil around their roots. Good growth is possible only if there is water in that soil. Most of us know from first-hand experience the disastrous effects on plants of drought and water restrictions.

In this land of often inadequate rainfall, it is essential that the rain or irrigation water that we do have produces the maximum benefit to our plants. That usually means that as much of it as possible must soak into our soil.

It is of course impossible for any soil to soak up all of the water in a deluge from a thunderstorm or a tropical downpour. Much of the water of light

showers falling onto already very wet soil may also not soak in. We can then be thankful that at least some of the water that runs from our soils will end up in reservoirs, perhaps for us to use later.

The rate at which water soaks into an already moist soil – the infiltration rate of the soil – is usually in the range 5–20 mm (of water) per hour. Infiltration rate is highest for sands and sandy loams and least for heavy clay soils, and is lower for sloping ground than for flat ground. The initial infiltration rates for soils that are fairly dry will be higher than the rates given in the table.

Here is what happens when rain falls onto a soil. The water enters the soil and fairly quickly flows down through any large holes, such as cracks, worm burrows and old root channels (p. 180). Some of the water soaks out from these large holes into the surrounding soil. Other water slowly soaks down from the surface between the large holes.

Infiltration of water will be slow if there are few or no large holes. It will be especially slow if the aggregates of the soil surface fall apart and form a crust.

Approximate rates at which water infiltrates already moist soil, as affected by soil texture

Soil texture	Infiltration rate	
	Flat ground	Sloping ground
Sand	20	8
Sandy loam	7	3
Clay loam	5	2

INCREASING INFILTRATION RATE

The rate of infiltration of water into a soil is increased when we:

1. Overcome crusting and prevent crust formation:

- Protect the soil surface with a mulch, preferably organic.
- Protect the soil surface with ground cover and other plants.
- Apply gypsum, if testing (p. 26) has shown it to be useful. Gypsum must be applied if your water is salty and has a high sodium content and low calcium content.

2. Encourage a large earthworm population:

- Increase the organic matter content of the soil through the application of compost.

3. *Improve soil structure:*

- Maintain or increase the organic matter content of loam and clay soils. Add up to 10 cm thickness of compost to the soil of new gardens. Mix the compost through the uppermost part of the soil profile. Earthworms and other soil animals will soon munch their way through the compost/soil mixture, making a new soil with a better structure. Repeated trenching is unnecessary if an active worm population is maintained. Worms have been shown to increase infiltration rates by as much as 10-fold.
- Prevent and relieve compaction. That means avoiding, as much as possible, walking on wet soils. Such walking compacts the soil by collapsing pores between aggregates, decreases the porosity of a soil, and so reduces infiltration rate. Your weight will only compact the top 80–90 mm of soil, but for infiltration of water that is an important part.

Most soils will compact, but often the effects are particularly severe if the particles in the soil have a wide spread of sizes, as in the loams. In such soils the smaller particles pack into the pores between the larger particles and block them. Compaction will be greatest during the first few days after rain or irrigation and becomes less likely as the soil dries out.

Don't dig the soil when it is very wet. Wait for one to two days after rain or irrigation. Digging is easiest after the soil has drained for this time.

- Remove any layering (p. 179). Dig 300 mm deep holes into the soil at a number of places around your garden, or at least where water ponds during the rainy season.

Look closely for any of the following:

A thin or thick layer of heavy clay or soil that has been cemented together. Such a layer may be very impermeable to water, as may be shown by the soil above it being very wet while that below is rather less wet. Try to break up these layers by hand or with machinery.

A very sandy layer under loam or clay soil will also slow the movement of water into the soil. Such layers are usually not natural, but have been put there by uncaring builders or left there by incompetent landscapers. Mixing the sandy layer into the soil above and below it will increase the rate of water movement into the soil.

- Check soil pH. Repeated, large applications of ammonium fertilisers (ammonium sulphate, urea) to already acid soils will reduce their calcium content and so can damage their structure. If your soil pH is around or below 5, and if digging is difficult and infiltration rate is low) you should expect much improvement from applications of gypsum and ground limestone.

4. Terrace your garden.

Terracing will slow the rate of water flow across the soil surface of sloping ground and will allow more time for infiltration. The combination of terracing and organic mulching is particularly effective.

5. Overcome repellence in sandy soils (see p.113).

6. Core and remove thatch from lawns.

Poor infiltration into lawns could be due to compaction or thatch build-up, or both. Coring and scarifying will usually overcome a problem caused by thatch. Poor infiltration caused by compaction usually means that the soil under the lawn has too much clay in it. If coring, combined with backfilling the holes with sand, does not improve infiltration, you may need to remake the lawn using a sandier soil. Coring is rarely needed on domestic lawns.

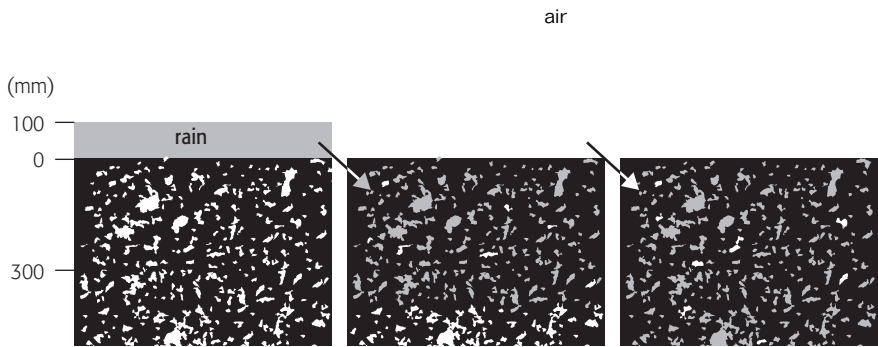
The soil of a lawn area that will be heavily used for games should be constructed with an upper layer of a sandy loam with no more than 12% clay and silt, and with the sand mainly of medium and fine grain size (0.1–0.5mm). It is useful to mix into the loam about 10% (by volume) well rotted and sieved organic materials to increase water holding capacity and the availability of nutrients. A top layer of at least 70 mm of this soil is desirable. Going to these lengths is not necessary if the lawn has little traffic on it. Then, any loam soil that is not sodic or hard-setting will do.



Terracing your garden.

WATER IN SOILS

If we are thirsty, we can drink a glass of water, right to the very bottom. Plants are not so fortunate: they cannot completely drain the reservoir of their soil,



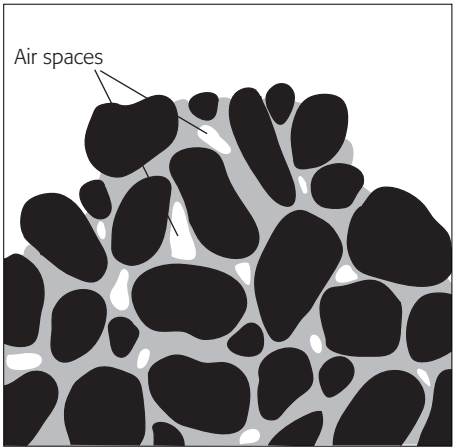
The same amount of rain penetrates more deeply into a sand than into a heavy non-cracking clay soil.

even if they are short of water. This section gives information about the size of the reservoir in different soils and the proportion of that water that can be used by plants.

Let us suppose that steady rain has delivered 100 mm of rain to your soil. That means that if the water were all sitting on the surface, it would cover the soil to a depth of exactly 100 mm.

We will assume that the soil was fairly dry before the rain. The plants growing in it would have needed watering within a couple of days.

Let us further suppose that all of the rain has soaked into the soil. While some has gone a long way down worm burrows, the average depth that is now moist will be something like 300 mm for a clay and up to 600 mm for a sand. It will have taken no more than a few hours for the water to finish draining down through the sand. Drainage down into a clay soil would have taken a few days.



In a soil at field capacity, water is held in the smallest pores and as a film on particle surfaces.

FIELD CAPACITY

When the main drainage of water down into a soil has finished, that soil (or rather, that part of it that is now wet) is said to be at field capacity. The reservoir is full to that depth.

Approximate amounts of water held in soils of different textures

Soil texture	The number of mm of water per cm depth of soil:		
	Needed to wet the soil to field capacity	Available to plants	Remaining at wilting point
Sand	0.9	0.7	0.2
Loamy sand	1.4	1.0	0.4
Sandy loam	2.3	1.4	0.9
Sandy loam plus organic matter	2.9	1.9	1.0
Loam	3.4	2.2	1.0
Clay loam	3.0	1.4	1.6
Clay	3.8	1.4	2.4
Well-structured clay	5.0	2.0	3.0

Note that many plants can use only a part of the water held in a soil at field capacity, but note also that many plants that evolved in seasonally dry parts of Australia can use much of the water remaining at so-called wilting point.

The soil is able to hold approximately this amount of water for long periods if evaporation from its surface, and transpiration by plants, is prevented. In a soil at field capacity, water has drained from the largest pores but all small and many medium-sized pores are filled with water. You can get an idea of what happens from the way that cooking water drains from the larger spaces between peas but leaves some water in the smaller spaces where the peas touch one another.

It follows from this that a given depth of a soil with many small and few large pores (clay) will hold more water than will the same depth of a soil with few small and many large pores (sand). Soils with many medium-sized (e.g. well-structured loams) have a large capacity to store water.

TRANSPIRATION: THE EVAPORATION OF SOIL WATER THROUGH PLANTS

One way of thinking of a plant is to imagine it as a bundle of flexible, narrow tubes running from root surface to leaf surface. The tubes are filled with water.

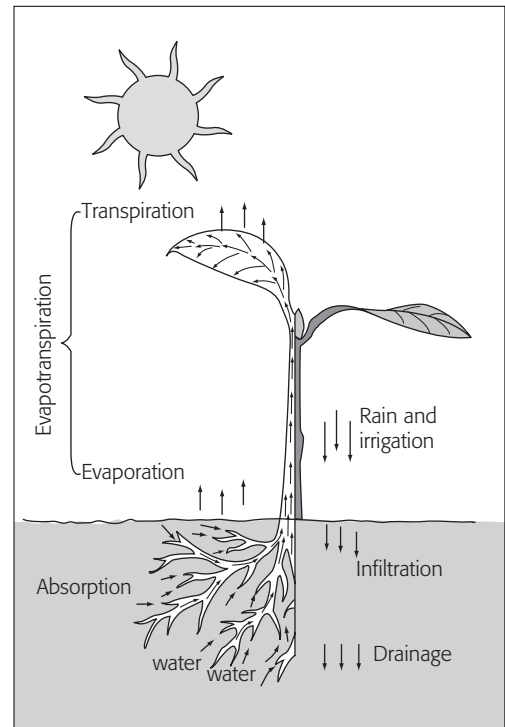
The bottom of each tube is open, but at the top end of each tube there is a shut-off valve that starts to close as the leaf around it gets a bit dry (wilts), or

when a signal from the bottom end tells it that there isn't enough water left in the soil to fill the tube.

The tubes end in hollows in the leaves just under valve-openings called stomata. When a stomate is open, water is evaporated through it into the surrounding air. This evaporation of water is called transpiration. The stomata of most plants are open during the day and close at night. (Those of cacti open at night, in an adaption that reduces the rate of water loss in the deserts from which they come.)

Transpiration creates a suction in the water-filled tubes inside the plant. This suction draws more water up through the plant and from the soil around its roots in much the same way that sucking on a straw raises iced coffee from a carton.

The rate of transpiration increases with increase in air temperature and wind speed and with a decrease in air humidity. Therefore, plants use water most rapidly on hot, windy, dry days. Transpiration keeps the plant cool, but it also means that in our gardens we must repeatedly supply more water.



Where water goes in soils and plants.

HOW PLANTS DEAL WITH A SHORTAGE OF WATER

If there is plenty of water in the soil, that furthest from soil particle surfaces – i.e. that in the largest pores – is easily pulled from the soil by transpiration. But as more and more water is removed from the soil, that remaining is held more and more firmly in smaller and smaller pores, so the plant is less and less able to extract it from the soil.

Eventually the plant is unable to extract enough water from the soil to make up for transpiration losses. With less water in the cells of the leaves than they are able to hold, they become 'floppy' and may shrink a little. We see this as wilting: the plant droops and its leaves may hang vertically or curl in on themselves (p. 181). These changes reduce total effective leaf area and hence the amount of heat reaching the plant.

At first the plant may wilt only briefly during the hottest part of the day and will recover within a couple of hours of sunset as transpiration is reduced and more water is taken up from the soil. If drying of the soil continues, the period of wilting starts earlier in the day and lasts longer.

Eventually the point is reached where daytime losses of water cannot be made up at night. The plant will then wilt permanently; it begins to wither and die.

AVAILABLE WATER

Soils still contain some water when plants are permanently wilted, but this water is so firmly held by soil particles that plants cannot extract it. Nor can it move to the roots fast enough to make up for transpiration losses. Those soils with large numbers of small pores – clay soils – will retain more water when plants are permanently wilted than will soils with fewer and larger pores – sandy soils.

The difference between the amount of water held at field capacity and that remaining when plants wilt permanently is the maximum amount of water that the soil can make available to plants.

The table on p. 160 shows that loams and some well-structured clays hold the largest amounts of available water. Note how adding organic matter to a sandy loam, or improving the structure of a clay soil, increases the amount of available water that can be held.

The table also shows that most of the water in sandy soils is available, while less than half of that in clays is.

Note also that a sandy loam or loam soil holds more available water than a sand. Therefore, adding both clay and organic matter to a sandy soil can more than double the amount of ‘plant-available’ water that it holds.

To improve the water-holding capacity of a sand, add 10–15 kg of crushed clay per square metre of soil and a 6–8 cm layer of organic matter and dig them in to at least spade depth, but preferably into the top 30 cm of soil. You will also need to add some superphosphate or other phosphorus source to build up a bank in the clay (p. 137).

Don’t bother adding sand to a heavy clay soil unless you are prepared to add a volume of several times that of the volume of soil being created, as discussed on p. 25.

EFFECTS OF WATER STRESS ON PLANTS

Plants grow most vigorously when the temperature and amount of light are right for them and they are never short of nutrients and water. A shortage of water causes stomata to partly or totally close, so that water loss through transpiration is reduced or stopped. This also reduces or shuts off the supply of carbon dioxide and so reduces or stops the manufacture of the sugars that are essential for growth. The more severe the water deficiency and the longer it lasts, the greater will be the reduction in plant growth.



This Silver Birch was allowed to become just a little too dry between drinks.

Flowering and fruit production is particularly hard hit by lack of water. If you do have to make a choice about where to reduce water use in your garden, don't skimp on vegetables such as lettuce, tomatoes and cucumbers. Drought causes lettuce to bolt to head, tomatoes to develop blossom end rot (p. 181) and cucumbers to become bitter. Fruit trees may drop much of their fruit. Development of the edible parts of onions, melons, beans, corn and eggplants will be greatly reduced if water supply is restricted in the early stages of their formation.

SOME BENEFITS OF WATER STRESS

Allowing established ornamental plants to become moderately water stressed is an effective way of keeping garden water use to a minimum. This is discussed further on p. 171. Stress also prevents excessive growth, so reducing the need for thinning and cutting back; disease problems often found in over-wet gardens are reduced.

Mild water stress during the later stages of ripening reduces fruit size and so improves quality. Rotting of soft fruits is lessened.

A COMMON ODDITY IN COOL AREAS

Often in the afternoon of a warm, sunny day in early spring you may be surprised to see your plants wilt. The soil is wet yet our plants seem unable to

get enough water. Adding more water makes no immediate difference but towards sundown they quickly recover.

In early spring warm air produces a high transpiration rate, but as the soil is still cold, the water in it and in the plants’ roots is rather viscous (a bit like cold treacle). The water cannot flow fast enough into and through the roots to keep up with transpiration losses.

This wilting effect disappears as the soil warms up.

WATERING

Much of the drudgery of watering Australian gardens during months of rainless heat has been removed for those gardeners who have fixed sprinkler systems hooked to electronic controllers. But even these systems must be programmed, so all gardeners need to know something about water and plants.

It is assumed that most readers want a pleasant garden, but want to keep the cost of maintaining it to a minimum. With water the most expensive item in maintaining a garden, that means minimising water use.

You must make sure that:

- As much as possible of rain and the water you do apply gets into the soil. See the section on infiltration (p. 156).
- You apply enough water to fill up the soil’s reservoir to the depth of the main root zone. See p. 154.

Length of watering periods at a glance						
Water required (mm)	Rate of delivery by sprinkler (mm/hr)					
	5	10	20	30	40	50
Sprinkler on for hours:						
30	6	3	1.5	1	0.75	0.5
40	8	4	2	1.25	1	0.75
50	10	5	2.5	1.5	1.25	1
60	12	6	3	2	1.5	1.25
80	16	8	4	2.5	2	1.5

- Loss of water from the soil itself is minimised. See the section on mulching (p. 74).
- Water use by your plants is no more than is needed to get the growth that you want. See the section on plants and water (pp. 160–1).

WATERING AT ITS SIMPLEST

Here are two simple ways of deciding when to water a part of your garden.

A. Wilt and water

1. Look in mid to late afternoon at the plants in your garden. You will be looking for the first signs of wilting – leaves taking on a somewhat dull appearance, curling in on themselves or starting to droop a little.
2. Water then if that plant and others like it must continue to grow rapidly or produce well.
3. Hold off watering for one or more days if it doesn't matter if the growth of the plant is slowed down. The longer you wait, the greater the saving in water, but the greater the reduction in growth of wilting plants.
4. Alternatively, water only the areas around plants showing obvious wilting and hold off on other areas.
5. When you do water, leave the sprinklers on for several hours, so that the soil is deeply soaked.
6. You can be a little more precise: Measure the amount of water delivered by your sprinkler(s) each hour (p. 167). Leave them on for long enough to deliver at least 20–30 mm of water to sandy soils and 40–70 mm to loams and clay soils. These amounts will bring the top 300 mm of soil – the main root zone – to field capacity. Note that many soils may not allow infiltration of water at rates that keep up with sprinklers delivering water at 20 or more mm per hour.

B. (Almost) letting your controller do it for you

Automatic controllers for fixed sprinkler systems are great, but we still have to tell them when to come on and for how long, and we need to know how much water will be delivered each hour. Here are two ways of using controllers.

Method 1

1. Set a starting time between bed-time and about 5 am. Loss of water by evaporation is least at night
2. Set a watering interval for each area. You will probably choose that the sprinklers come on once each few days to once each three weeks during the least rainy part of the year.
3. Set an 'on' time in the range 1 to 5 hours, as shown by past experience.
4. If you want to be more precise: Measure the amount of water delivered each hour by the sprinklers in each area (see below). Leave them on for long enough to deliver at least 20–30 mm of water to sandy soils and 40–70 mm to loams and clay soils.
5. Switch the controller off during the wetter part of the year, or when the law demands it.

Method 2

You decide that except when you are away from home, you will vary the controller's program to suit the weather. You might even decide to use the 'wilt and water' method and just use the controller to turn the sprinklers on and off while you are asleep.

INTERVALS BETWEEN WATERINGS: A ROUGH GUIDE

The growth and producing capacity of fruit trees, vegetables and annual flowering plants suffer if they get dry. Of all the plants in your garden, they will need the most frequent watering. Probably you will need to water them every 1–5 days in summer, 4–20 days in spring and autumn and not at all in a southern winter or a northern Wet.

Established ornamentals and lawns can be watered at intervals of about 2–3 times as long as those for vegetables etc.



Typical water meter.

GETTING TO KNOW YOUR SPRINKLERS

If you want to use water efficiently, you must know how much water each of your sprinklers delivers each hour and over what area.

You can find out by using one of three methods.

Method 1.

Use the water meter. Read the meter, run the sprinkler(s) at the desired setting for an hour and re-read the meter. Divide the number of litres used by the area watered in square metres to get the mm of water delivered each hour to the area.

Example: Meter readings 4263.725 and 4264.150

Difference 0.425 kilolitre (kL) = 425 litres

Radius of watered area 3 m

Therefore area watered = $\Pi r^2 = 3.14 \times 3 \times 3 = 28.3 \text{ m}^2$

Average amount of water delivered $425/28.3 = 15 \text{ mm/hr.}$

MAKE SURE THAT NO OTHER WATER IS USED DURING THE TEST!

Additional calculations are needed when areas watered by moveable sprinklers overlap one another.

Example: The sprinkler used above is run at the same setting for 1 hour in each of 4 positions needed to cover a lawn.

Total water used: $4 \times 425 = 1700 \text{ litres}$

Area watered 81 m^2

Average amount of water delivered $1700/81 = 21 \text{ mm}$

Method 2.

Turn the sprinkler on the required amount and let it run inside a rubbish bin or drum for a known time. Measure the amount of water delivered and use that figure in calculations similar to those above.



A bucket is suitable for measuring water delivery rate from a rose, but you will need a rubbish bin for a sprinkler.



It takes only an hour to run a can test.

Method 3.

Those with fixed sprinkler systems and no meter can get an idea of the amount of water delivered by using a 'can test'. Divide an area between two rows of sprinklers into equal squares and place a can in the centre of each square. Any fruit, soup or pet food can will do. Run the system for one or two hours and measure the depth of water in each can with a ruler whose zero is right at the end. Average the readings to get the average amount of water delivered.

The 'can test' can also be used to test for evenness of watering from a single sprinkler or a fixed system. The wider the variation between cans, the less acceptable the sprinkler. Large variation between cans means that you will have to water for longer than is suggested by the average figure so that dry spots do not develop.

Evenness of watering is important for lawns but much less important for shrubs and trees as these have much more extensive networks of roots and so can take extra water from wet spots. A shrub or tree will grow satisfactorily even when only 70% of its root system is irrigated.



The average height of water in the cans, in mm, is the irrigation rate for the sprinklers at the water pressure used during the test.

YOUR CLIMATE AND YOUR GARDEN

Of course you know that you must water more frequently in hot weather than in cool weather, but do you really know how much water can be lost from your garden on a sunny day, or on a cool, cloudy day?

Water is lost from a garden partly by evaporation from the soil and partly by evaporation (transpiration) from plants. These two amounts are often grouped together as evapotranspiration (ET).

The amount of water lost by evapotranspiration from a thoroughly watered garden is about the same as that lost from a swimming pool or pond of the same surface area. Losses are greatest on hot, cloudless, windy days of low humidity and least under a thick, chilly, still fog.

The table below gives average daily amounts of water lost from well-watered gardens in various Australian cities and towns. Of course losses will be higher on days that are hotter than average and lower in cooler days. We will see soon how to allow for such days.

Approximate daily amounts of water lost from well-watered gardens in various parts of Australia. (mm per day)

Place	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
COASTAL												
Hobart	4	4	3	2	1	1	1	1	2	3	3	4
Melbourne	6	6	4	3	2	1	1	2	3	4	4	6
Brisbane	5	4	4	3	2	2	2	3	4	4	5	6
Adelaide	7	7	5	4	2	2	2	2	3	5	6	7
Sydney	6	5	4	3	2	2	2	3	4	5	6	7
Perth	8	7	6	3	2	2	2	2	3	4	6	7
Townsville	7	6	6	6	5	4	5	6	7	8	9	8
Darwin	6	6	5	6	6	6	7	7	8	8	7	7
INLAND												
Canberra	7	6	5	3	2	1	1	2	3	4	5	7
Griffith	8	7	5	3	2	1	1	2	3	5	6	8
Mildura	9	9	6	4	2	2	2	3	4	5	7	9
Moree	9	8	7	5	3	2	2	3	4	6	8	9
Merredin	11	10	8	5	3	2	2	2	3	6	7	10
Alice Springs	11	10	8	6	4	3	3	5	6	8	9	11
Oodnadatta	14	14	11	7	5	3	4	5	7	10	12	14

USING EVAPORATION FIGURES

Here are the simple steps to be taken in using evaporation figures to provide your plants with enough water, without waste.

BASIC METHOD FOR VEGETABLES, ANNUAL FLOWERS AND FRUIT TREES.

1. Read from the table opposite the amount of water that can be safely removed from the soil before plant growth is harmed.

Example: Vegetables in a sandy loam rich in organic matter; 0.8 mm/cm depth.

2. Assume that their roots penetrate to 30 cm (p. 182).
3. Calculate the amount of readily available water in this reservoir.

Example: $30 \text{ cm} \times 0.8 \text{ mm/cm} = 24 \text{ mm}$ readily available water.

4. What month of the year is it?

Example: January

5. Where do you live?

Example: Perth

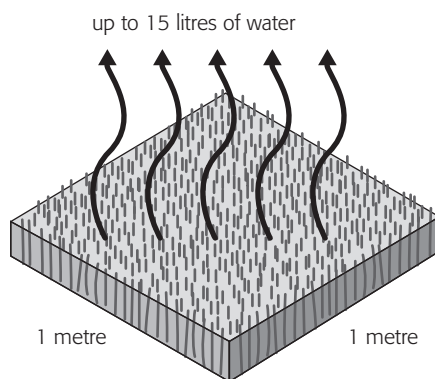
6. Read from the table on p. 169 the average daily amount of water likely to be lost during that month.

Example: For Perth in March the average daily loss is 8 mm.

7. Divide the amount of available water by the average daily loss.

Example: $24 \text{ mm} / 8 \text{ mm per day} = 3 \text{ days}$.

8. Apply 24 mm of water every 3 days if the weather has been 'average'. Apply an extra 10–20% if your water is saline.



On a very hot summer day each square metre of well-watered lawn can lose as much as 15 litres of water.

Variation

1. Let's suppose that since last watering you have had two days of heatwave: Double the rate of evaporation for these two days. For the examples above, that would mean watering one or two days after the last watering.

2. Let's suppose that the first two days after the last watering were very cool. Halve the rate of evaporation for those days, so apply water one day later, that is, after 4 days.

Approximate amounts of water that can be extracted from soils before watering is necessary. Figures are mm of water per cm depth of soil.

Soil texture	Vegetables	Fruit trees	Lawns Lush	Lawns Acceptable	Ornamental trees and shrubs	Drought-tolerant Australian native plants
Sand	0.3	0.3	0.4	0.6	0.6	0.7
Loamy sand	0.4	0.4	0.6	0.8	0.9	1.2
Sandy loam	0.5	0.7	1.0	1.2	1.3	1.8
Sandy loam rich in organic matter	0.8	0.9	1.2	1.6	1.8	2.3
Loam	0.9	1.0	1.5	1.8	2.0	2.6
Clay	0.4	0.5	0.8	1.1	1.3	2.8
Well structured clays	0.7	0.8	1.1	1.6	1.9	3.5

BASIC METHOD FOR ESTABLISHED LAWNS AND HARDY ORNAMENTAL PLANTS OF 'ACCEPTABLE' APPEARANCE

Ignore this section if you want your lawn and all of your ornamental plants to always look lush and to grow rapidly.

Water use by most lawn plants and hardy ornamental plants can be minimised by allowing them to become a little stressed between waterings. The calculations are the same as those above for vegetables, but a higher figure for the amount of available water in the soil should be used. Also, the evaporation figures can be multiplied by a number between 0.3 and 0.6. This allows for the fact that by the time these plants have used most of the available water in the soil, they are transpiring at a much lower rate than they would have if they had been fully supplied with water.

Example: As for vegetables, but with evapotranspiration in March being $0.5 \times 8 \text{ mm} = 4 \text{ mm}$ per day and the soil holding 1.6 mm water per cm depth. Therefore the time between waterings in average weather conditions is $(30 \text{ cm} \times 1.6 \text{ mm/cm}) / 4 \text{ mm/day} = 12 \text{ days}$.

You could try for further water savings by using a factor of 0.4 or even 0.3 instead of 0.5. Some of the more sensitive grasses will soon tell you if you are going too far.

Most warm-season grasses (p. 200) are very deep-rooted, so you can use a depth of something like 60 cm for the root zone in the calculations.

METHOD FOR A BUSH GARDEN

Exotic and Australian native plants that have evolved in dry climates can usually get by with no water other than that provided by rain. They will, however, thin themselves out to cope with this and so will soon look like they would in the bush – foliage somewhat thinned at times and some bare soil in between fairly widely separated plants if your area has long dry seasons.

Nevertheless, such plants will give you a garden even if your water supply is severely limited.

Many native plants are deep-rooted and are able to use water very sparingly. They are able to use more of the water in a soil than is available to softer plants. In fact, they are able to remove much of the water that remains at so-called ‘field capacity’.

Thus, if in an area such as that around Mildura the average annual rainfall of 284 mm all soaks into the soil, it might bring the soil to field capacity to a depth of 120 cm (so giving an available amount of water of perhaps $120 \text{ cm} \times 2.1 \text{ mm/cm} = 252 \text{ mm}$). Evaporation averaged over the year will be about 5 mm per day. Multiplying this by a factor of 0.14 gives a daily average evapotranspiration of 0.7 mm, so the 252 mm of water in the soil should last for $252 \text{ mm} / 0.7 \text{ mm/day} = 360 \text{ days}$, that is, about a year. The area was originally covered by native trees and shrubs, so the factor of 0.14 must be about right for this bush.

SOME FURTHER THOUGHTS

1. Young plants have shallow root systems. Water them more frequently than the number of days calculated using a rooting depth of 30 cm, that is, use a root zone depth of 15 cm.
2. Evaporation figures for capital cities are usually measured in open areas somewhere near the city centres. If you live in the drier plains areas of Sydney, Melbourne, Adelaide and Perth you could multiply the evaporation

figure by up to 1.2 to allow for extra evaporation in your area. If you live in a higher, cooler hills area (e.g. the Dandenongs or the Adelaide Hills) you could multiply by 0.8 to allow for a lower evaporation rate.

3. If you find that for your situation watering as calculated above allows the plants to wilt before the next watering is due, you should recalculate using a shallower reservoir depth, or a lower figure for soil water content.
4. Many bentgrass lawns that have been cut very short will have roots penetrating to no more than 10–15 cm. Check by digging a hole. They need to be watered at double the frequency given by the calculations above. It is recommended that you cut higher to allow deeper root growth, or preferably replant with grasses that have deeper root systems.

SOME GENERAL WATER-SAVING HINTS

- Water infrequently and to the full depth of the root zone. You can work on a minimum depth of 30 cm, but up to 60 cm for warm season grasses. Frequent and shallow watering usually produces plants with shallow root systems and poor drought tolerance.
- With established plants that do not need to grow rapidly – ornamental trees and shrubs and lawns – try gradually increasing the length of time between waterings. The more a soil is allowed to dry out, the lower will be losses of water by evapotranspiration. You may find that you can apply much less water than you have been using, while still keeping your garden's appearance the way you like it.
- Plants that you want to grow rapidly and produce prolifically – vegetables, plants being established, fruit trees, annuals – will use water most efficiently if they have ample supplies of all nutrients.



Death by excessive tidiness. Cutting entry of water (and oxygen) into the root zone by spreading asphalt or other impermeable material is a sure way of giving a tree a lingering death.



Small leaves are one adaptation used by plants to survive extended periods of drought.

- On the other hand, heavy fertilisation of established ornamental plants is unnecessary and unwise because the extra growth produced will increase their use of water.
- Most gardeners in dry areas try to lessen the harshness of their surroundings by producing a cool, green oasis around the house. That's easy enough if the water is available, but if your supply is limited you can still reduce the temperature around the house through the use of drought-tolerant trees and shrubs that will get by with a minimum of water.

Choose trees and shrubs that:

- are native to the area, or that come from areas of similar climate;
- are known to develop deep and extensive root systems;
- store water in enlarged roots and stems;
- have grey or hairy leaves – indicating the presence of an effective mulch on them;
- have thick, leathery leaves with waxy surfaces;
- have small, vertically oriented leaves;
- protect themselves by shedding old leaves rather than allowing new shoots to die.

- Cacti, many succulents and bromeliads are particularly efficient in their use of water as they open their stomata only at night (p. 182).
- Group plants of similar water requirements. For example a corner of drought-tolerant Australian native plants and exotics may never need to be watered after establishment, whereas a mixture of drought-tolerant natives and water-loving exotics would need repeated watering. This arrangement would use much more water than would separate plantings and the natives could well have shortened lives through excessively rapid growth or the development of root rots.
- Plant windbreaks around isolated houses to reduce evapotranspiration in the garden.
- Mulch wherever possible during the dry season, but note that organic mulches can increase the risk of frost damage during cooler months.
- Areas shaded by buildings will lose less water than areas in full sunshine, unless of course, the soil is thickly populated with shallow roots from trees.
- Weeds use water too: remove them (p. 183).
- The extensive, shallow root systems of trees such as the birch, willow and ash readily invade well watered areas of soil. Successful growing of vegetables in such soil is difficult. Annual cutting of the roots to spade depth or deeper may be necessary.
- Wherever possible, divert roof water onto the garden during dry times of the year. A gate valve and diversion pipe is often all that is needed.
- If water is in limited supply, reserve it for young plants and for those at critical stages of growth.
- Planting well ahead of hot weather will enable plants to withstand drought by developing deep root systems.
- Diseased plants use water inefficiently; those with root diseases may not be able to use much of the water in a soil. Adequate nutrition, addition of plenty of organic matter to encourage biological control, and some use of chemicals, will all help combat diseases.
- It is not advisable to leave water on the leaves of vegetables such as cucumbers, zucchinis, tomatoes and strawberries and others that are especially susceptible to fungal diseases (p. 183). Watering with drippers is preferable for these.

- Watering before a forecast hot spell will decrease stress on plants during the heat, and will be more efficient than watering during it.
- All sprinklers mist if the water pressure is too high, but those with small holes tend to mist more easily than those with larger holes. Severe misting can cause losses of as much as 90% of the applied water on windy days. Reduce misting by keeping water pressure down or by switching to sprinklers with larger holes.
- Apart from misting losses, evaporation from droplets from overhead sprinklers can cause serious losses of water. The amount lost varies with droplet size and weather conditions. Losses as high as 50% have been measured on hot, dry, windy summer afternoons in Perth. On calm, hot days, losses would usually be less than half this, less again on cooler and/or more humid days, and least at night. These losses are partly made up for by lowered evapotranspiration during sprinkling, but overall, watering by sprinkler is most efficient between sunset and sunrise.
- Sprinkle on hot, windy days only to save badly wilted plants. Never do it during the day if your water is saline as your plants can be killed by the highly saline water falling on them.
- Late afternoon and evening watering allows water to remain on plant leaves overnight. In humid areas this encourages the spread of fungal diseases. In such areas it is best to water early in the morning.

DEALING WITH TOO MUCH WATER

‘Too much’ water can cause us problems through:

- Soil erosion;
- Waterlogging.

SOIL EROSION

Erosion is the process of removal of particles from a soil surface by wind or water.

Erosion by water is prevented or reduced by:

- Maintaining a full cover of plants so that the soil is protected from the pounding of raindrops and is held together by a mass of roots.



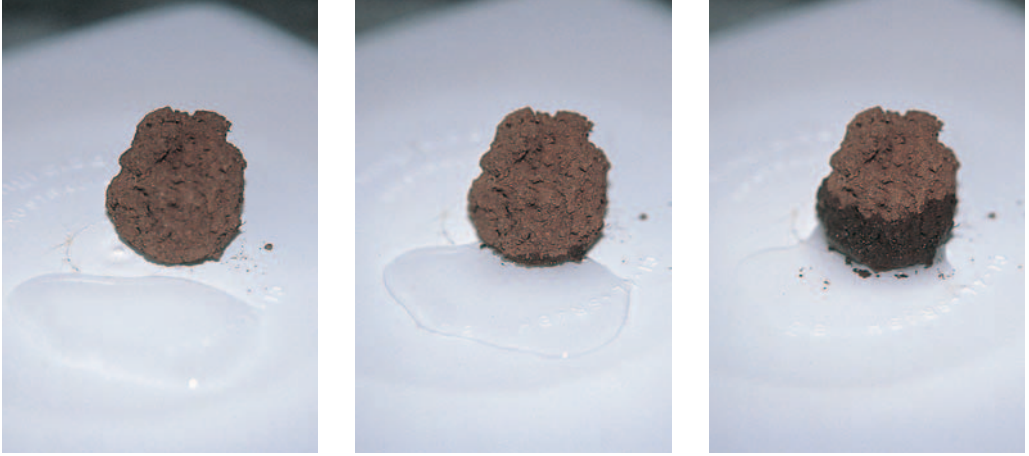
Marginal and interveinal scorch caused by severe potassium deficiency on sandy soils.



One cup of iron sulphate mixed through one bucket of compost and inserted into holes made in the root zone provides long-term cure for iron deficiency in slightly alkaline soils.



Proteoid root cluster on a container-grown *Grevillea*. These clusters secrete acid, chelating and other chemicals that dissolve phosphorus from the growing medium and transport it back into the plant.



Soils hold water because of attraction between the surfaces of soil minerals and water.



Layers of soil of different texture buried during building or landscaping will restrict water movement into soils and create wet and dry patches in a garden.



Worm tunnels allow rapid entry of water into soils.



The 'hang-dog' look of these shrubs shows that they are desperate for a drink.

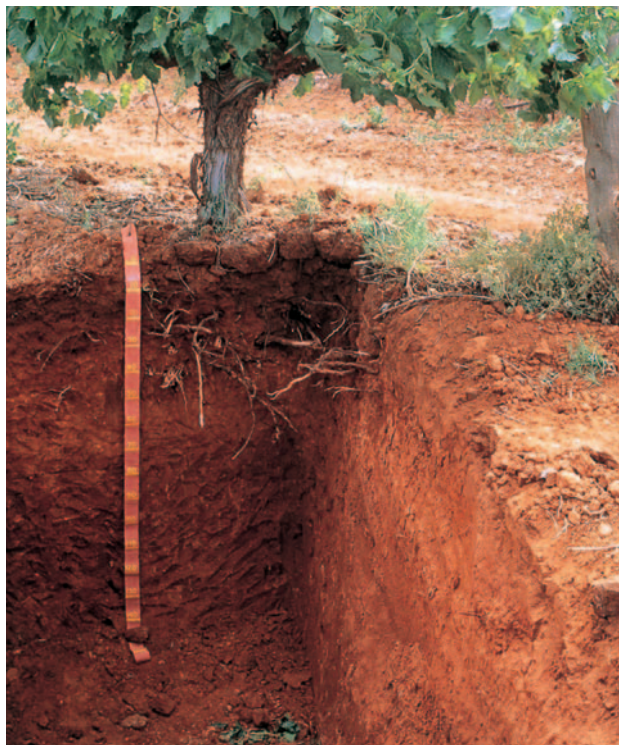


Response to a 40°C north wind when you can't move into shade.



Allen Gilbert

Blossom-end rot in tomatoes is caused by a lack of calcium in the developing fruit, which in turn can be brought about by a period of inadequate water supply.



John Coppi

Most roots are in the top few hundred millimetres of soil.



Cacti open to the world only at night.



Weeds steal water and nutrients from young trees. This one has no hope of growing quickly.



Spread of fungal diseases in vegetables such as zucchini is encouraged by leaving their leaves wet overnight.



Continuous water seepage has severely damaged the grass of this lawn.



This grass was killed by salty water being pumped from a swimming pool.



The effect of salty water on plant roots. Dried sultanas such as that on the far left swelled to near their original size when soaked in pure water (second from left), then lost some of the water when dropped into salty water (third from left), or did not take up water from very salty water (right).



Salinity due to sodium chloride causes this sort of damage to grapevine leaves.

- Allowing water to spread in thin sheets rather than being concentrated into narrow streams of destructive force.
- Terracing sloping sites.
- Protecting areas of temporarily bare soil – as when planting vegetables – with an organic mulch or with shade cloth. Water flowing from upslope should be diverted into drains.
- Improving soil structure so that water entry into the soil is rapid.

These measures are especially important in tropical and subtropical areas because of the high intensity of rain in these areas.

WATERLOGGING

A soil is said to be waterlogged if most of its pores are filled with water. There is no room for air and its vital ingredient oxygen, which is needed by all plant roots.

Some plants thrive in water or in waterlogged soils by bringing oxygen from the air to their roots via their leaves and stems. Few of us want to grow only rice, taro, sago palms or reeds, so we need something other than a swamp in our gardens.

Some plants survive in soils that are waterlogged for part of the year. River Red Gums, alders, willows and pandanus are examples, but most of the plants we grow in our gardens need an ample supply of both water and oxygen in the soil around their roots.

Some are damaged by even short periods of lack of oxygen in the soil. Rhododendrons are particularly sensitive. Their roots are killed by one day of waterlogging. When so damaged, the shoots may look normal enough during cool weather, but will rapidly die during the first days of heat in spring or summer, water supply to the leaves from the almost non-existent root system will not be able to keep up with transpiration. If some of your plants die during the first warm weather, suspect that the real cause was earlier waterlogging, whose cause should be found and corrected.

Signs and symptoms of waterlogging

Plants announce their suffering from waterlogging by wilting, appearing stunted, yellower than normal and with the margins of the oldest leaves sometimes developing dark spots and, with prolonged waterlogging, through the loss of leaves and death of root tips or whole plants (p. 183).

Waterlogging reduces plant growth mainly because it slows oxygen movement into, and carbon dioxide from, the soil: the roots suffocate. And as oxygen is less soluble in warm than in cool water, waterlogging usually has more severe effects in warm climates than in cool, and the effects are more rapid.

Waterlogging also causes alcohol, ethylene and methane and soluble iron, manganese and sulphides to be produced in soils in amounts that are toxic to some plants. These toxins aggravate the effects of suffocation; both toxins and suffocation weaken plants and reduce their ability to resist attack by pathogens such as *Phytophthora*.

The roots of most plants do not grow into a waterlogged part of a soil so one effect of overcoming waterlogging is that roots are able to grow further into the soil. Being in contact with a greater volume of soil, these plants are then better able to withstand drought in dry weather.

You need to take action if your soil:

- has a continuously wet surface;
- has moss and/or slimy algae growing on its surface;
- kills or maims your plants in wet weather;
- has a smell of rotten egg gas when you dig into it;
- has free water at less than 30–40 cm below the surface.

Prevention of waterlogging

Find whether the cause of waterlogging is drainage from upslope and/or a impermeable layer in the soil and/or poor soil structure, and then:

- install a drainage system and/or;
- break through the impermeable layer and/or;
- improve soil structure (p. 23).

DRAINAGE SYSTEMS

Drainage systems can be any of the following.

- Grassed surface drains installed across a slope and in such a way that erosion is prevented. They are useful in diverting away from gardens or houses surface water flowing down slopes.

- Surface drains lined with flat stones or loose pebbles. These may be useful in allowing large flows without erosion, and soakage into the soil at low flows.
- Sand-filled slits that will rapidly take excess surface water down to slotted drainage pipes and so away from the area.
- Subsurface drainage lines. These will be needed if a water table persists within 50 cm of the surface.
- Success with sand slits and subsurface drains depends on matching their design to the soil of the area. It is recommended that you engage a qualified firm to design and install any drainage system needed.

GARDEN WATERING SYSTEMS

There are four main types of watering systems.

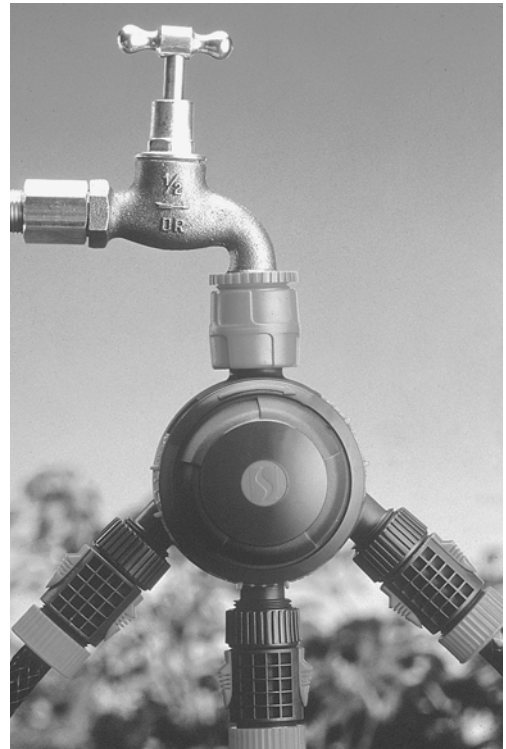
- Sprinklers connected to hoses and moved by hand
- Travelling sprinklers
- Trickle systems
- Other fixed systems.

SPRINKLERS ON HOSES

Sprinklers connected to hoses are the cheapest. With them we can put the water where we want it for as long as we like. The main disadvantage is that we need to be there to shift them and turn them on. Tap-timers allow automatic turnoff.

TRAVELLING SPRINKLERS

Travelling sprinklers are very useful for large, level lawns that are relatively close-cut.



Tap-timers save water for busy people.

TRICKLE SYSTEMS

The key part of a trickle irrigation system is a 'dripper' or emitter from which water can flow at a slow rate. The water goes straight onto the soil surface.

Trickle systems are used mainly as an efficient way of getting high yields from grape vines, fruit trees and vegetables. They are often turned on daily or every other day so that the roots are always amply supplied with water.

Main advantages

- Evaporation losses are reduced by comparison with sprinklers.
- The root zone of the plant can be easily kept near field capacity, so keeping the plant growing at near its maximum rate.
- Salts in water are washed to the outer margin of the wetted zone. Therefore water of higher salinity can be used than is possible with sprinklers.
- Dripper lines are easily controlled automatically.
- Drippers are especially suited to fruit trees, but they are easily adapted to long-lived vegetables.
- Drippers are useful for difficult-to-water areas, e.g. steep slopes.



Raised garden beds are good for old backs as well as for providing excellent drainage in low-lying gardens.

Some disadvantages

- Drippers need to be checked regularly for blockages: a good quality filter is essential. A good pressure regulator is also essential. The rate of water delivery from each dripper is only constant at a constant pressure.
- Over-watering can easily occur: occasionally check the soil around drippers.
- Too few drippers per plant, especially in sandy soils, will restrict root growth and allow plants to be more easily blown over. Desirable areas per dripper range from ½ to 1 square metre for sandy soils in hot localities to 3 square metres for heavier soils in cooler places.
- Operating drippers under established ornamental shrubs and trees in the same way as under fruit trees will waste large amounts of water (p. 171). Don't run established ornamentals and fruit trees on the same line if you want to save water. One survey in Perth showed that people who installed drippers under shrubs doubled their use of water without improving plant growth!



Drippers are less useful than micro sprinklers in home gardens.

FIXED SPRINKLER SYSTEMS

In fixed sprinkler systems the pipes carrying the water to the sprinklers are permanently installed in the soil or on its surface. In-ground installation is essential for lawns. Both in-ground and surface installation can be used in garden beds. Microsprinklers that spray water under trees and shrubs often give better coverage in garden beds than do larger fixed sprinklers, whose water can be intercepted by foliage.

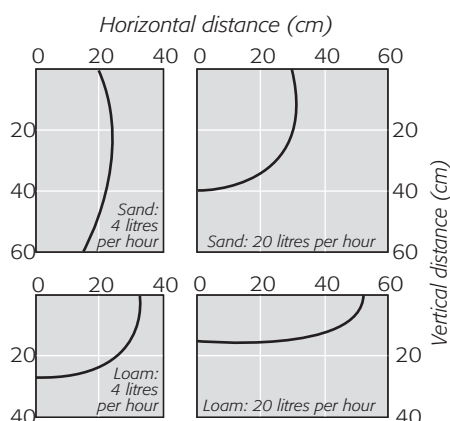
Advantages

- They save a lot of time.
- Watering is taken care of even when you are away from home.
- If they are well designed, they water evenly and thoroughly.

- Watering can be programmed for the period before sunrise when evaporation losses are lowest.
- Watering can be programmed to take account of the infiltration rate of the soil.

Disadvantages

- They are initially more expensive than movable sprinklers.
- They need maintenance.
- Some local councils do not allow them.
- Unless programmed properly they waste water. One test in Melbourne showed that automatic systems applied 60% more water than was needed. An Australian Water Resources Council publication concludes '... Fixed sprinkler systems contribute to ineffectual use ... of water for garden requirements'. Watering by the clock takes no account of variations in weather and hence the needs of plants. But careful programming will allow you to be just as efficient in your use of water with automatic systems as with manual methods.
- Most of the pop-up sprinklers of fixed systems produce fine droplets and much mist if operated at too-high pressures. Evaporation losses can be high and salinity problems aggravated.

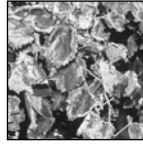


Water from a dripper does not move sideways very far in sandy soils, so roots tend to be concentrated into a small part of the whole soil, unless the drippers are very close together. Increasing the rate of delivery of water will widen the wetting zone a little.

CONSIDER THESE POINTS BEFORE YOU CHOOSE A SYSTEM

- Microsprinklers are ideal for areas of trees, shrubs and groundcover plants. Sprinklers are installed at various heights so as to be above groundcover plants but below tree branches. Microsprinklers with heads giving quarter and half circles of coverage are useful for edges and corners.
- Travelling or impulse sprinkles are useful for lawns, but lawns also lend themselves to watering with pop-up fixed sprinklers.
- Use rotating arm, butterfly or single hole sprinklers for easily accessible areas.

- Large holes in sprinklers give large drops; small holes give smaller drops. Large drops damage bare soils more than do small drops. Use mulches to protect the soil.
- Eliminate runoff by adjusting the rate of watering to below the infiltration rate of the soil. For most soils that means that the application rate should be less than 20 mm per hour, and for some, less than 10 mm per hour. Many older pop-up sprinkler systems deliver at about 50 mm per hour. Their 'on' periods must be short and interspersed with 'off' periods to allow infiltration. For example, you could set the controller to run the sprinklers on a 15 minutes on, 30 minutes off cycle until the required amount of water has been delivered.
- Several manufacturers now offer low-volume, low-pressure sprinkler heads that produce medium-sized water drops, and therefore minimal evaporation losses, and application rates low enough to prevent ponding or runoff from soils with low infiltration rates.
- Use a kitchen timer or alarm clock to remind you to turn off sprinklers if you don't have a tap-timer.
- If your water is salty, allow as little of it as possible to fall on plant leaves. Drippers and under-tree sprinklers are useful.
- If you want a fixed system that is controlled automatically, have it designed by competent people, AND LEARN TO USE IT BY FOLLOWING THE GUIDELINES IN THIS BOOK.



9 Gardening with salty water

This chapter is more relevant to those whose water supplies are saline (salty) than to those many gardeners in eastern Australia whose tap water has a very low level of salts. Nevertheless, all gardeners will find some interest in this section, as it will enable you to avoid damaging your plants with the salinity of fertilisers.

WHAT IS SALTY WATER?

All waters have some salts dissolved in them. They could all be said to be salty, but for gardeners it is usual to consider water to be salty only if the concentration of salts in it is high enough to damage at least some plants (p. 184).

On p. 53 we learnt that all salts are combinations of ions. Here is one way that you can use that information.

The simplest way of describing the salts in salty waters is by detailing their separate ions. The main ions in water supplies are sodium, calcium, magnesium, chloride, bicarbonate, carbonate and sulphate.

The amount of damage caused by salty water depends on:

- The total concentration of all ions.
- The proportions of the different ions.
- The type of soil being irrigated by the water.
- The types of plants being grown.

HOW DO I KNOW WHEN MY WATER IS SALTY?

The simplest way of finding the saltiness of your water if you are on mains supply is to ring your water supply authority. They will give you a figure for the electrical conductivity (EC) of the water they supply to your area. Use the table below to interpret what they tell you.

Those not on mains supply will need to have their water analysed by a laboratory. Ask for the EC to be measured.

The higher an EC reading, the saltier the water. EC readings are given in units called microSiemens per centimetre ($\mu\text{S}/\text{cm}$) or deciSiemens per metre (dS/m). One $\text{dS}/\text{m} = 1000 \mu\text{S}/\text{cm}$.

An EC number tells you how salty your water is but it does not tell you anything about the concentrations of the different ions present. Some ions are much more damaging to plants and soils than are others.

If your water has an EC above $500 \mu\text{S}/\text{cm}$, you should find out about the concentrations of ions in it, and its total alkalinity. Ring your water supply authority or have your water tested.

Interpretation of EC readings	
EC range ($\mu\text{S}/\text{cm}$)	Interpretation
0–500	Very low to low salinity, suitable for all plants
500–750	Sensitive plants, including ferns and fuchsias, show burn around the edges of leaves and leaf drop if they are repeatedly misted with water of this quality. Application to the soil or potting mix should cause few problems other than tip damage to liliun.
750–3000 leaves	Increasing numbers of species show reduced growth, burning of and eventually death as EC rises through this range.
>3000	Unsuitable for irrigation except for tolerant plants being grown in sandy soils with excellent drainage.

HOW SALTS DAMAGE PLANTS

Relative to pure water, salty water slows seed germination, stunts growth and retards flowering. Salty water damages plants in several ways.

- Repeated additions of salty water to a soil gradually increase the concentration of salts in the water in the soil. These salts reduce the amount of water that plants can get from a soil and also make them work harder for what they do get.

This little experiment shows what happens. Place a dried sultana in a glass of tap water (p. 184). Within a few hours the sultana will have absorbed water and will have swollen to about its size when it was picked. Water has moved into the sultana because the concentration of soluble materials (sugar) inside is higher than that outside. Now add two tablespoons of common salt to the water. The sultana will begin to shrink again. Water moves from the less concentrated to the more concentrated solution.

Normally the water inside plant roots has a higher concentration of salts than does the water outside them. But increasing saltiness of the water around roots reduces the movement of vital water into them. The plant cannot use as much of the water in the soil. It wilts sooner, and this greatly reduces its growth. The proportion of soil water that it can use is much less than if the water were not salty.

For example, a plant growing in a loam that holds 75 mm of water in the top 30 cm at field capacity would be able to use about 58 mm of the water before starting to wilt. But if you added ammonium sulphate to the soil at a rate of 100 g per square metre and did not water it in thoroughly, the plant would be able to use only about 35 mm of the water before wilting.

- The sodium of salty water damages the structure of clay soils. What happens is that sodium gradually replaces calcium and magnesium on the surfaces of particles in the soil, so creating a 'sodic' soil. As long as the irrigation water remains saline, the aggregates in the soil may remain intact, but if salinity falls (as during rain) the aggregates fall apart. Particles 'float off' or disperse into the soil water and clog the soil pores, so forming a compacted layer at the surface.

Roots are less able to push their way through the soil as it becomes more sodic. They are therefore less able to reach water and plant nutrients. The higher the concentrations of calcium and magnesium ions in the water, relative to sodium, the less will be the damage to soil structure. Put another way, 'hard' salty waters (those that reduce lathering of soap) are less damaging than 'soft' salty waters, such as those that have passed through water softeners.

- The chloride and sodium ions of salty waters accumulate at the outer edges and tips of the oldest leaves, where they kill cells. We see this as a browning and burning of leaf edges and tips and death of whole leaves (p. 184). Leaf area is reduced; there is less green plant to capture sunlight so plant growth slows.
- The nutrient element boron is present in high enough concentrations in some water supplies to damage sensitive plants. Violas and pansies are especially sensitive: they are damaged by water with as little as 0.5 mg per litre of boron.
- High concentrations of bicarbonate and carbonate ions in water can raise soil pH and interfere with the supply of iron to plants that need very acid soil.
- High concentrations of chloride ions reduce the firmness of tomatoes and also increase the succulence of leaves, and so their proneness to disease.

COPING WITH SALTY WATER

- Keep the water off leaves. The leaves will be damaged by salts left behind when water on them evaporates. Use drippers or under-tree sprinklers.
- Water only at night, so that loss of water by evaporation as it flies through the air is minimised.
- Reduce evaporation from the soil through mulching. This will reduce total water use and therefore the total amount of salt added to the soil. Over a 20 week period, bare soil can come to have double the salinity of soil under mulch.
- Improve soil structure by applying gypsum, if testing shows that it will be beneficial (p. 26), and by adding large amounts of organic matter (p. 105).
- Do not let the soil dry out, as this will cause the concentration of salts in the remaining water to become very high. This effect is greatest in sandy soils.
- Leach excess salts from the soil. Leaching is easiest when soil structure is good. Add 10–20% more water than is needed to fill the soil reservoir (p. 160) each time you water.

- Well-fed plants are better able to tolerate salinity than are poorly fed ones of the same species. Soluble fertilisers need to be applied on the basis of a little, often, otherwise they will aggravate the salinity problem. Use slow-release sources of nutrients, including organic matter.
- Use fertilisers that have most of their nitrogen in the nitrate form rather than in the ammonium or urea form.
- When using salty water on potted plants, you should add enough water each time to allow about 10% to drain from the pots.
- Do not mist plants with salty water. If you do, their quality will quickly deteriorate.
- Do not water pot plants with water that has passed through a water softener. These remove calcium and magnesium from the water and replace it with sodium.
- Don't give up even if your water is so salty that despite all your best efforts many plants still grow poorly. Concentrate on the many salt-tolerant plants that can be grown. Make up a shandy of salty water and rainwater for use on more sensitive plants.

USING EFFLUENT WATERS

Severe restrictions on the use of water could lead many gardeners to consider recycling to their gardens as much as possible of the water used inside the house.

Bathroom effluents, containing mainly soap, should not cause any problems. However, considerable care must be taken with laundry effluents if serious problems are to be avoided.

Laundry detergent powders contain only about 15–20% of a detergent, with the rest being various compounds of sodium. These sodium compounds make the effluent very alkaline (pH 9.2 or higher) and their accumulation over a period could raise the pH of some soils to a level that is high enough to damage plants. The high sodium content will seriously damage soil structure (p. 194).

BIODEGRADABLE

Ajax Plus is biodegradable according to tests recommended by the National Health & Medical Research Council.

RECYCLABLE

This carton contains recycled material and is recyclable.

INGREDIENTS

AJAX PLUS contains ingredients to remove dirt from clothes (anionic surfactant), soften water and disperse soils (sodium polyphosphate), remove bleachable stains (sodium perborate), break-up fatty soils (sodium carbonate, sodium silicate), improve the appearance of white fabric (blueing agent), and improve product processing (sodium sulphate), also small quantities of fabric brightener, soil suspending agent, colour and perfume.

AJAX PLUS is safe for all your family's washables — coloureds, synthetics, blends, washable woollens and permanent press. Take your normal extra care for hand-washables.

MONEY BACK GUARANTEE

If you are not satisfied with the performance of AJAX PLUS, Colgate-Palmolive will refund the purchase price of this pack. Send the pack and remaining contents to:

Laundry effluent water containing boron from detergents must not be used in gardens.

Some laundry detergents contain boron. Effluent waters containing this boron will be toxic to many plants.

Those who must use laundry effluent water on their gardens should use liquid detergents that contain no boron, or plain soap.

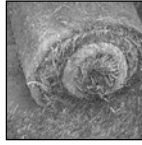
Never, ever, use borax as a washing brightener if you want to use your laundry effluent on your garden.

LISTS OF PLANTS WITH DIFFERENT TOLERANCES TO SALTS

Very sensitive				
<i>Acanthus mollis</i>	Blackberry	<i>Dahlia</i>	Holly	Primula
African violet	Broom	<i>Euonymus alatus</i>	<i>Lilium</i>	<i>Rhododendron</i>
Avocado	<i>Camellia</i>	<i>Feijoa</i>	Linden	Roses
Beans	Carrot	Ferns	Onion	Spruce
<i>Begonia</i>	<i>Cedrus atlantica</i>	<i>Fuchsia</i>	<i>Phormium</i>	Strawberry
<i>Berberis</i>	<i>Cotoneaster</i>	<i>Gardenia</i>	<i>Photinia</i>	Violet
Sensitive				
<i>Abelia</i>	<i>Clivia</i>	Lavender	Plum	<i>Zinnia</i>
Apricot	<i>Ficus benjamina</i>	Lettuce	<i>Poinsettia</i>	
<i>Arbutus</i>	<i>Gladiolus</i>	<i>Magnolia</i>	Radish	
<i>Aster</i>	Honeysuckle	<i>Nandina</i>	<i>Strelitzia</i>	
<i>Capsicum</i>	Junipers	Peach	<i>Viburnum</i>	
Moderately tolerant				
<i>Agapanthus</i>	Cabbage	Cucumber	Lantana	<i>Pyracantha</i>
<i>Agave</i>	Carnation	<i>Cyclamen</i>	Pear	Sweet corn
Apple	<i>Casuarina equisetifolia</i>	<i>Elaeagnus</i>	<i>Philodendron</i>	Sweet potato
<i>Brunfelsia pauciflora</i>	<i>Chrysanthemum</i>	Golden willow	Potato	
<i>Buxus</i>	Citrus	<i>Hakea suaveolens</i>	Privet	

Tolerant				
<i>Asparagus</i>	<i>Calocephalus</i>	<i>Eucalyptus microtheca</i>	Fig	Olive
Beetroot	<i>Casuarina glauca</i>	<i>Eucalyptus occidentalis</i>	Grape	Rockmelon
<i>Bougainvillea</i>	<i>Dodonea viscosa</i>	<i>Eucalyptus pileata</i>	Hibiscus	Rosemary
Broccoli	<i>Dracaena</i>	<i>Eucalyptus robusta</i>	<i>Myoporum</i>	Spinach
<i>Callistemon</i>	<i>Eucalyptus botryoides</i>	<i>Eucalyptus sideroxylon</i>	<i>Oleander</i>	Tomato
Very tolerant				
<i>Acacia cyanophylla</i>	<i>Casuarina</i>	<i>Lagunaria patersonii</i>	<i>Pelargonium</i>	
<i>Acacia cyclops</i>	<i>Correa</i>	<i>Leptospermum laevigatum</i>	Pigface	
<i>Acacia longifolia</i>	Date palm	<i>Lippia</i>	Saltbush	
<i>Acacia pulchella</i>	<i>Eucalyptus camaldulensis</i>	<i>Melaleuca armillaris</i>	<i>Tamarix</i>	
<i>Arctotheca</i>	<i>Eucalyptus sargentii</i>	<i>Melaleuca diosmifolia</i>	<i>Westringia</i>	
<i>Banksia</i>	<i>Eucalyptus spathulata</i>	<i>Melaleuca nesophila</i>	<i>Yucca</i>	
<i>Callistemon</i>	<i>Hibbertia</i>	Norfolk Island Pine		

The book *Grow What Where* by the Australian Plant Study Group contains an extensive listing of Australian native plants of known high tolerance to saline soils.



10 Lawns

Take a good long look at your lawn, or at that part of your garden plan that says 'lawn'. Do you really need as much lawn as you have or plan to have? Think how boring a lawn is compared with an ever-changing bed of flowering shrubs, ground-cover plants or vegetables. They all need water, but in contrast to sheep, humans often find vegetables more enjoyable and interesting than grass.

But, you might protest, we need some lawn to give the garden a feeling of space, and as a play area for our children/grandchildren. OK, you can have some lawn, but plan ahead and do the job thoroughly, so that maintenance of your lawn is easy.

CHOOSING THE BEST LAWN GRASS FOR YOUR AREA

Choose grasses that are adapted to your climate. They will get closer to looking after themselves than will grasses more suited to hotter/cooler/



It's a matter of opinion, but many will find the garden on the left to be less interesting than that on the right.

wetter/drier climates. Ask a well-established local lawn specialist or your local garden advisory service for guidance. The box on the next page gives some general information.

The many grasses that can be used for lawns can be placed into two groups. The so-called cool-season grasses grow mainly in the cool part of the year; warm-season grasses grow mainly or only in the warmest and hottest parts of the year.

Warm-season grasses are much more efficient in their use of water than are cool-season grasses. This efficiency results from differences in internal chemistry. This efficiency and their ability to push roots deep into the soil makes warm-season grasses more drought tolerant than cool-season grasses.

The tall fescues have deeper root systems than do other cool-season grasses so they tend to have better drought tolerance, but they still use much more water than do warm-season grasses of equally good appearance.

Cool and humid

(Tasmania, southern Victoria, NSW mountains and tablelands)

Kentucky bluegrass, fescues, ryegrass, kikuyu, couch

Cool winters, dry summers

(Adelaide, Perth, inland Victoria)

Couch, buffalo, tall fescue, kikuyu, saltwater paspalum

Warm to hot and humid

(Coastal Sydney to north of Brisbane)

Couch, Queensland blue couch, buffalo, kikuyu

Tropical

Couch, blue couch, carpet grass, buffalo

CULTIVARS AND COMMENTS

Many named cultivars are available for most of the grasses. Here are some of those names, with a few comments on their characteristics.

- **Couch:** Santa Ana, Wintergreen (also called Casablanca), Windsor Green and Greenslees Park are the most widely grown cultivars. All give denser lawns than does common (seeded) couch. The first two tend to stay green longer in winter than do other cultivars.
- **Buffalo:** Common buffalo produces a rather harsh-feeling lawn. New cultivars such as Velvet have a softer feel.
- **Saltwater paspalum:** Common names for it include Salteen and Sunturf. This grass is suited only to areas where salty water does not allow other grasses to be grown.

Lawn grass information

Mowing height	cm	Salt tolerance	
Couch	1.5–3	Couch	medium
Queensland blue couch	1.5–3	Queensland blue couch	very good
Broadleaf carpet grass	1.5–3	Broadleaf carpet grass	poor
Saltwater paspalum	1.5–3	Saltwater paspalum	excellent
Buffalo	5–7.5	Buffalo	medium
Kikuyu	2–4	Kikuyu	very good
Tall fescue	5–7.5	Tall fescue	medium
Kentucky bluegrass	3–7	Kentucky bluegrass	poor
Perennial ryegrass	2.5–5	Perennial ryegrass	medium
Fescues (other)	2.5–6	Fescues (other)	poor
Bentgrasses	0.5–2	Bentgrasses	medium

Shade tolerance

Couch	poor	Couch	very good
Queensland blue couch	poor	Queensland blue couch	very good
Broadleaf carpet grass	good	Broadleaf carpet grass	poor
Saltwater paspalum	good	Saltwater paspalum	very good
Buffalo	excellent	Buffalo	fair
Kikuyu	poor	Kikuyu	excellent
Tall fescue	good	Tall fescue	very good
Kentucky bluegrass	fair	Kentucky bluegrass	fair
Perennial ryegrass	medium	Perennial ryegrass	good
Fescues (other)	poor	Fescues (other)	good
Bentgrasses	medium	Bentgrasses	poor

Wear tolerance**Drought tolerance**

Couch	good	Couch	5.5–7.5
Queensland blue couch	excellent	Queensland blue couch	5.5–6.5
Broadleaf carpet grass	poor	Broadleaf carpet grass	4.5–5.5
Saltwater paspalum	excellent	Saltwater paspalum	6–8.5
Buffalo	good	Buffalo	6.5–7.5
Kikuyu	excellent	Kikuyu	6–7.5
Tall fescue	fair	Tall fescue	5–8.5
Kentucky bluegrass	medium	Kentucky bluegrass	6–7
Perennial ryegrass	fair	Perennial ryegrass	5.5–8.5
Fescues (other)	fair	Fescues (other)	4.5–6
Bentgrasses	poor	Bentgrasses	5.5–7

Soil pH preference**Range**

- **Kikuyu:** This aggressive grass is not recommended for home gardens because it will invade garden beds unless lawn edges are trimmed regularly.
- **Tall fescue:** Commonly used cultivars include Shortstop, Falcon and Marathon. Tall fescues are more drought tolerant than are other cool-season grasses.
- **Kentucky bluegrass:** The cultivars are all fairly similar to one another. This grass requires ample water in summer if it is to retain a good appearance.
- **Perennial ryegrass:** This is another heavy water user.
- **Chewings fescue:** This will compete with other cool-season grasses only if soil pH is fairly low (about 5) and soil phosphorus level is low.
- **Bentgrasses:** Shallow rooting means that these grasses must be watered frequently in dry weather. They are for use only in the coolest southern areas.

PREPARE THE SOIL PROPERLY

You cannot remake your lawn each year, so take the time to prepare the soil properly in the first place.

- Dig a few holes to see if there is any layer of compacted soil that will slow down percolation of water and prevent roots from growing deep into the soil. A compacted layer must be broken up or have holes punched through it.
- Mix any buried layer of sand with the soil above and below.
- Remove builders' rubble, large rocks and the like.
- Install a drainage system (p. 186) if you know or suspect that the soil might become waterlogged in wet weather.
- Check the pH of the soil. Add lime (p. 56) if the pH is lower than is needed by the grasses you want to grow. The high pH of alkaline soils can't usually be lowered, so for them, choose one of the grasses that grow well on alkaline soils.



Use a Levelawn to smooth the soil before laying turf.

- Apply fertiliser to correct any deficiencies in plant nutrients. You will probably need to add a base supply of phosphorus using superphosphate (50–100 g per square metre) or reactive rock phosphate (150–300g per square metre). The surest way of adding the right amount is to have the soil analysed. The expense is small compared with the benefits.
- Apply gypsum if testing (p. 26) shows that it is needed.
- Use the natural soil of the area if it has a sandy loam or loam texture and drains well.
- If the soil is mainly clay subsoil or if it has a poor structure, add a layer of sandy loam about 200 mm deep. (But first apply gypsum.) The sandy loam will still allow rapid infiltration of water even when it is compacted, but clay soils probably will not. Keep a small stockpile of the sandy loam for filling hollows that appear before sowing. Mixing a small amount of sand into a clay soil will not improve its structure.
- Level the soil.
- Install the fixed sprinkler system, if you are having one. Level the soil again.
- Heavily water the area.
- Fill any hollows with the chosen topsoil.
- Roll the soil and again fill hollows.
- Eliminate weeds and weed seeds. Wet the soil so that at least some of the weed seeds in it germinate. The seedlings can be removed mechanically, or killed with a herbicide. Much hand weeding may be needed over the next couple of years. Pre-emergent herbicides applied just before the time of the year when seeds of the worst weeds germinate may reduce your workload.

WHEN TO SOW OR PLANT

The best time of year for sowing/planting a lawn depends on your climate and on the type of grass to be used.

- Grasses that grow best in the cool seasons of the year should be sown/planted from autumn to spring.

- Grasses that grow best in warm weather should be sown/planted in mid to late spring.
- Avoid the hottest period of the year.
- In southern areas, avoid the very wettest part of the year.
- Avoid times when water use on gardens might be restricted.
- Try to avoid sowing seed at times of the year when very heavy rain is likely.

SOWING SEED

- Scatter the seed as evenly as possible over the area. Divide the full amount of seed into four equal parts. Scatter one-quarter over the whole area as you walk from one side to the other. The other three-quarters are scattered as you walk in the opposite direction to that taken the first time, and in the two directions at right angles to the first two.
- Lightly rake the seed into the surface.
- Water gently, so that the seed does not float into clumps.
- During the week after sowing it is critically important that you water frequently so that the seed never gets dry. That could sometimes mean a light sprinkling every few hours.
- Watering frequency can be reduced once the seed has germinated.

PLANTING SPRIGS

Some warm-season grasses do not produce seed so you must use small clumps – sprigs – of the grass. Squares of grass can be bought, or you can use edge trimmings from a friend's lawn.

Break or cut the grass squares into pieces of about 2×2 cm and insert them into core holes. Spacings are usually in the range 10–20 cm. The closer the spacing, the sooner you will have complete cover. Water thoroughly, and repeat at least daily for the first week.

LAYING STRIPS OR SQUARES OF TURF ('INSTANT LAWN')

- Have the turf delivered no more than one day before you lay it.

- Keep the exposed surfaces of the turf moist by frequent light sprinkling. Do not cover them with plastic sheeting.
- The soil surface must be lower than the surrounds of the area by the thickness of the soil layer of the turf
- Spread a light dressing of lawn fertiliser over the levelled soil and rake it into the soil.
- Water the soil a day or two before laying the turf
- Lay turf strips up and down sloping ground. Start at the bottom of the slope. Peg it in place on steep slopes.
- Start laying the turf along a straight edge of the area. Roll out the strip and pull it hard up against the edge.
- Lightly tamp the turf with a broad, flat tool made from thick boards and a pole.
- Any hollows should be filled by spreading more soil under the turf; any humps should be removed from underneath the turf.
- Stand on a wide plank placed on the first strip when laying the next strip.
- Stagger joints as when bricks are being laid.
- Do not have short pieces of turf at the ends of rows of turf. Rather, have full pieces at each end of a row and any short piece needed towards the middle.
- Trim the turf with a sharp kitchen knife when it has to be fitted around curves or cut to fill a gap.



Planting sprigs is an easy way of starting a lawn.



Stagger joints when laying turf.

- Water the turf within an hour of laying in warm weather, sooner in hot.
- Water daily to several times each day for the first two weeks in warm to hot weather, less frequently in cool.

EARLY CARE OF NEW LAWNS

- Apply lawn fertiliser at a rate of about 20 g per square metre each two weeks to seedling and sprig-sown lawns so that you get rapid coverage. Reduce the frequency once you have full cover.
- Mow as soon as is possible – probably about one month after sowing seed. Mowing will encourage the grass to thicken up.
- Once you have full cover, give the soil a thorough and deep soaking, if rain has not done this for you. Your aim is to make sure that the subsoil is moist.
- Then increase the time between waterings, so as to encourage the roots to grow deeply into the soil.
- All this effort will be wasted if you do not regularly wander over your lawn and remove weeds while they are young. Letting them go to seed or allowing such nasties as creeping oxalis to spread unchecked will soon give you a weed patch. A few minutes each couple of weeks will keep your lawn looking attractive.

A FEW HINTS ON WATERING LAWNS

- If restrictions on the use of sprinklers mean that lawns can only be watered by hand, it may be better not to water them at all. Let them go brown. The rhizomes of grasses such as Kentucky bluegrass, couch, blue couch, Chewings fescue and creeping bent will remain dormant underground and will soon send up shoots when the first rains come.
- Infrequent deep watering (p. 173) allows the surface soil to dry out; this reduces disease problems and should eliminate the growth of slimy algae and moss. It also discourages the growth of shallow-rooted weeds.

	Warm-season grasses		Cool-season grasses	
	Couch grass	Buffalo grass	Tall fescue	Kentucky blue grass
Watering frequency	Water used, as a percentage of that used by frequently watered tall fescue			
Very frequent	69	61	100	96
Moderately frequent	57	50	90	84
Infrequent	49	49	83	78

The table above shows that a lawn of warm-season grasses that is watered infrequently will use only half the amount of water needed to keep a lawn of cool-season grasses looking good.

All the lawns except the infrequently watered Kentucky blue grass looked equally good.



A few minutes of hand watering will wet no more than the top few millimetres of the soil under a lawn. Within a few months, such shallow watering will give you a weedy, thin and unsightly lawn.

MOWING

Although this book is mainly about soils, mowing must be mentioned because it has a big effect on what happens at a 'grassroots' level in soils under lawns.

Root growth depends on photosynthesis in leaves. The sudden removal of leaves caused by mowing inevitably reduces root growth for a while. A cycle of rank growth and scalped grass caused by very infrequent mowing will severely damage roots. The weakened plants with their shallow roots have a poor ability to withstand drought or other stress. Soon all you will have is a weed patch.

Mow frequently enough so that you never remove more than one-third of the green leaf area at any one mowing. That could mean twice each week at the peak of the growing season to less than monthly when there is little growth.

Mow cool-season grasses fairly high (p. 201). That will usually be much higher than most Australians have their lawns. We are too much influenced by bowling and golf greens. You probably don't want to spend the time on your lawn that is lavished on greens, so do yourself a favour and mow high.

High-cut cool-season grasses will have stronger root systems than will short-cut grass of the same type. The roots will be exploring a greater volume of soil. Tolerance to heat will be increased and water can be applied less frequently. Close-cut lawns wilt long before those cut higher. However, total water use may be a little higher than for a close-cut lawn, but at least you will have a lawn rather than mostly weeds and bare soil.

Note that these remarks about cutting height are for cool-season grasses. Warm-season grasses have the ability to produce deep root systems even when they are cut quite short. You are not being encouraged to cut them very short, but they will still have an excellent appearance even when they are cut much shorter than is recommended for cool-season grasses.

For cool season grasses, keep mowing height moderately high during spring, raise it during summer and gradually lower it during autumn. For warm season



Tall-cut cool-season grass has a deeper root system than closely mown grass, and is better able to withstand stress.

grasses, mowing height can be high during spring, gradually lowered during summer and then raised again during autumn to promote winter hardiness.

Lawn grasses may suffer water stress after mowing because root growth may be temporarily stopped. So water soon after mowing, but in humid weather wait until the cut ends of leaves have dried and so become sealed against disease organisms.

Don't mow on days when the temperature is likely to exceed 35°C.

Don't mow immediately after watering or substantial rain. Doing so may compact the soil.

TOPDRESSING

Bowling and golf greens are regularly topdressed to help decompose thatch. Topdressing is not often necessary in domestic lawns. But if you do want to even up a lawn surface, note the following.

- Use a sand or sandy loam that has a similar texture to that of the existing soil.
- Add no more than 5 mm at one time: don't cover the leaves.
- Brush the topdressing into the lawn and then water.
- You can include fertiliser with the topdressing.
- Small areas can be topdressed using a drop-type fertiliser spreader.

DEALING WITH THATCH

Thatch is a layer of dead and living shoots, stems and roots that develops on the surface of the soil below the leaves of lawn grasses (p. 233). A thin layer of thatch is desirable because it gives spring to a lawn and cushions the soil against compaction. A thick layer is undesirable because it can reduce water penetration into the soil, increase disease problems and allow scalping of the grass.

Rapid development of a thick layer of thatch means either that you have killed earthworms in the soil through use of benlate or insecticides such as carbaryl, that you have allowed the soil to become too acid, and/or that you are applying far too much fertiliser.

By all means have a thick layer of thatch removed mechanically, but then check soil pH and apply lime as needed, check for earthworms and introduce some if there are none, and reduce fertiliser applications to those suggested below.

CORRECTING PH

Most lawn fertilisers acidify soil. Therefore check the pH of the soil under your lawn each year or so. Lawn plants growing in soil more acid than their preferred range have decreased heat hardiness and are more prone to disease; thatch build-up is encouraged. Apply agricultural lime or a 1:1 dolomite/lime mixture to increase pH.

COMPACTION

Clay soils under lawns can be severely compacted by heavy use for games or general traffic (p. 233). The resulting poor drainage can seriously reduce root growth and lead to a rapid decline in lawn quality. The compaction can be temporarily relieved through coring (p. 233). Remove the core material and replace it with sandy loam. Long-term care of heavily used lawns is easiest if the uppermost 200 mm of the soil is a sandy loam.

FERTILISING LAWNS

LAWN FERTILISING AT ITS EASIEST

- Use a mulching mower so that losses of nutrients from the lawn are minimized.
- Annually, apply IBDU or urea formaldehyde – synthetic slow-release sources of N – at a rate of 30–40 g per square metre; apply potassium sulphate at 15 g per square metre once a year just before the season of slowest grass growth.
- For soils that are amply supplied with phosphorus, that's it.

SECOND EASIEST LAWN FERTILISING

- Buy a fertiliser specially formulated for lawns. The fertiliser will have an NPK content of something like 10: 2: 6.

- Buy a fertiliser spreader.
- Apply the fertiliser at a low rate at the beginning of the main growing season, but not when it is too cold for the grass to grow. A typical rate is 20 g/m² (0.8 kg per 40 square metres). Half this rate could give satisfactory results if clippings are not removed.
- Note that the rate recommended here may be lower than that recommended on the bag. There is little point in adding large amounts of fertiliser that will give large amounts of growth that will have to be removed by mowing.
- Your aim should not be maximum growth, but acceptable appearance with minimum work and minimum use of fertiliser and water. The amount of fertiliser will be just enough to replace the nutrients being lost in the clippings.
- Continue to apply the fertiliser at a low rate every couple of months.
- Towards the middle of autumn in southern Australia, replace half of your application with an equal weight of potassium chloride or potassium sulphate. The extra potassium will toughen up the grass.
- Do not fertilise dormant grass or grass which for any reason you cannot water.
- Consider reducing the amount of work you need to do by converting some of your lawn into well-mulched, attractive plantings of shrubs and trees, or by mowing your existing lawn with a mulching mower.



Cheap and effective lawn fertiliser spreader.

GENERAL HINTS ON FERTILISING LAWNS

- Fertiliser use is minimised if you use a mulching mower. These mowers chop clippings very finely, so that they quickly decompose and recycle their nutrients to the living plants. They do not usually add to thatch formation. Leaving clippings tends to make a lawn more drought tolerant and greener in winter. It has less moss, more earthworms and the rate of infiltration of water is higher than when clippings are removed.
- Apply soluble fertilisers on the basis of a little and often.

- Water a lawn thoroughly before applying soluble solid fertilisers. Allow the leaves to dry off, apply the fertiliser and then **WATER AGAIN IMMEDIATELY TO PREVENT LEAF BURN.**
- Lawns on some heavy (clay) soils are often improved by applications of gypsum. Use the test given on p. 26. Apply about 500 g per square metre if the test shows that gypsum will be beneficial. Such an application should improve drainage and soil aeration for a year or more. Further annual applications may be needed with some soils.
- By keeping a record of the times and amounts of fertiliser that you apply to your lawn, you will avoid over and under-fertilising.
- Lightly fertilised lawns tend to use less water than do nearby unfertilised lawns of the same type.
- A lawn that does not respond to fertiliser might have the wrong type of grass for your climate, or it might be suffering from the effects of compacted soil, disease or a nutrient imbalance.

If nutrient imbalance is suspected, have the soil analysed. The report will indicate which plant nutrients need to be added for a balanced supply. Specify that you want analyses for pH, available phosphorus, trace elements and exchangeable potassium, calcium, magnesium and sodium.

- Correct any deficiencies indicated by the report. An application of trace elements will last for many years.
- When establishing a new lawn on soil that was bush or farmland until recently, apply single superphosphate at 40–50 g per square metre, or as indicated by analysis, to provide a ‘bank’ of phosphorus.



Mulching mowers minimise the amount of fertiliser needed by lawns.



- When analysis indicates that the soil under your lawn has a high level of phosphorus, you need not add more phosphorus for several years.
- Yellowing of lawn grasses, even when fertiliser is applied regularly, is often a sign of iron deficiency. This deficiency is especially likely if your soil has a pH above 6.5. Mild deficiency can be corrected for a few weeks with an iron sulphate spray containing 3 g per litre. Severe deficiency that is not corrected with iron sulphate might be corrected with an iron chelate, but the best long-term cure is to grow a grass such as couch, buffalo or kikuyu that is adapted to neutral to alkaline soils. Temporary yellowing during the 'wet' in the tropics can also be cured with iron sulphate.
- Iron sulphate also gives good control of moss and algae, but these will quickly return unless you correct poor drainage and stop over-watering – two factors that are essential to the growth of moss and algae.
- Excessively high levels of nitrogen increase shoot growth at the expense of root growth. Ability to withstand heat stress, drought and wear is greatly reduced; total water use and susceptibility to disease are increased; we waste money and we waste time with extra mowing. Go for quality of lawn (p. 234), not quantity of clippings.
- Don't apply nitrogen to dormant grass. It might green up a bit, but it will be weakened, be more prone to diseases, and may be severely harmed by weeds stimulated by the nitrogen.
- The potassium contained in lawn fertilisers improves wear tolerance and increases heat, drought and cold tolerance.
- Lawns containing clover will need rather higher applications of phosphorus than will all-grass lawns. The extra phosphorus is easiest to supply by each year substituting a general garden fertiliser for one of the applications of lawn fertiliser. An alternative is an annual application of single superphosphate at about 30 g per square metre.
- Lawn grasses are very efficient at taking up soluble nitrogen from the soil. There is usually no need to add more nitrogen to allow for that removed by shrubs and trees from soils under lawns as the shrubs and trees get little of that applied anyway.
- Applications of potassium to some very sandy soils may eventually produce magnesium deficiency. The grass takes on a yellowish colour and is stunted. Magnesium deficiency is corrected in very acid soils (pH below 5.5) by the application of dolomite at 30–50 g per square metre.

Correction in less acid soils is by several applications of magnesium sulphate (epsom salts), each at about 10 g per square metre. Water thoroughly to prevent damage through high salinity.

LAWNS FOR ORGANIC GARDENERS

You will use a mulching mower so that you do not repeatedly remove nutrients from the lawn. It is likely that your lawn will not be a grass monoculture, but will have both grasses and clovers.

You will have built up the soil with reactive rock phosphate and/or poultry manure before planting the lawn. The soil will have the texture of a loam, with about 20% clay, so that it has a high ability to supply potassium and to retain nutrients that are readily leached from sandy soils.

Clover, clay and return of clippings will mean that your need for fertiliser will be minimal. Extra nutrients can be supplied via any of the products listed on p. 132. You will want to avoid using any materials that may contain weed seeds. Heat-treated, pelletised poultry manure will be useful, but its high phosphorus content, relative to nitrogen, means that it should not be the only fertiliser used. Many garden stores sell organic/natural mineral fertiliser mixtures that are worth trying.

Those organic gardeners whose soil is sandy should amend the soil with clay (to supply and hold nutrients) and/or crushed granite dust (to supply potassium) and/or zeolite (to hold nutrients). Acid soils should have their pH raised with a mixture of limestone (to supply calcium), dolomite (to supply calcium and magnesium) and wood ash (to supply some phosphorus and much potassium) (about 1:1:1).

The relatively low levels of potassium in some 'organics' in relation to their nitrogen content means that their repeated use on some sandy soils may eventually lead to disease problems and poor growth if clippings are not returned to the lawn.



11 Growing plants in containers

Growing plants in containers (pots, baskets, tubs) is easy (p. 235), as long as you understand a few basic facts about potting mixes and plant needs.

STARTING OFF

- Decide where you want to place a potted plant.
- Assess the light level of this place (very sunny, morning sun, afternoon sun, outdoor shade, indoors) and also the likely temperature range at different times of the year.
- Go to a garden centre and buy a plant of a size and type suited to the place where it is to sit.
- Bring it home.
- Water it as needed.
- Apply liquid fertiliser weekly to monthly or apply a controlled-release fertiliser every 3–9 months.
- Sit back and enjoy the plant.
- Get more enjoyment by buying more plants.

POTTING-UP AND REPOTTING

Eventually, some of your plants will get too large for their pots and you will want to pot-up (pot them up into a larger pot) or to repot them (trim their roots and return them to the same pot). Here is how to do it.

COMMON SIGNS OF A NEED TO POT-UP OR REPOT ARE:

- large tops causing easy toppling;
- yellowing growth;
- frequent wilting;
- the plant's crown being forced out of the pot;
- many roots circling around the outside of the rootball and growing through drainage holes – the potbound condition.

Young, rapidly growing plants may need to be potted up every few months. Established plants might not need to be repotted any more often than every 1–3 years. Don't do it more frequently than is necessary. Prolific flowering and attractive tops are often most easily attained from slightly potbound plants.

Proceed as follows (see p. 236):

- Water the plant during the evening before starting, or at least a couple of hours before.
- Assemble requirements such as new pots, potting mix that conforms with the Australian Standard, a knife and secateurs.
- If your main method of fertilising is via controlled-release fertilisers, you should now mix the recommended amount of fertiliser through the amount of mix you are going to use. Also, add wetting agent (see p. 230).
- Trim or pull off any roots that are growing from drainage holes.
- Place one hand over the mix, with the plant stem between index and middle fingers, or supported in some other way.
- Upend the pot and, while holding its base with the other hand, move the pot and plant rapidly through the air for a short distance. Stop the hand holding the pot but allow the hand holding the plant to continue to move. This action usually jerks the plant and rootball from the pot. If this doesn't work, sharply tap the rim of the pot down on to the edge of the table or bench. Make sure that all the leaves are out of the way.
- Inspect the rootball. Cut away any obviously diseased or damaged roots.
- Remove roots circling around the outside of the rootball. Remove those at the bottom by pulling and cutting. Those around the sides can be teased out

if they are fairly short. Alternatively, shave off the outer 10–15 mm from the bottom and sides of the rootball with a sharp knife and/or secateurs.

- Keep the roots moist under drying conditions or if you are interrupted.
- You can return the plant to the same pot or you can pot-up. Using the same pot or one of the next larger size will be easy enough if you have shaved off the outer part of the old rootball. If you have not, it will be difficult to get new mix in around the rootball unless you go up more than one size of pot.
- Add enough new potting mix to the pot to allow the top of the old rootball to be 15–20 mm down from the top of the pot.
- Position the rootball in the centre of the pot.
- Fill new mix around it. Firm the mix gently, but do not compact it. Do not fill past the old fill-line on the stem.
- Scratch the top of the rootball to break any algal crust.
- Water thoroughly.
- Do not prune the tops, as this will reduce the amount of new root growth.
- Leave undisturbed and allow the mix to dry somewhat before re-watering.

TUBS

Should you periodically go through the hassle of repotting mature plants in large tubs? If the plant is healthy, and the mix is not sinking, there is no need to repot. Check the pH of the mix about every 6 months and adjust it if necessary (p. 266). Make sure that you leach salts out every year or so. Use ‘complete’ fertilisers at low rates of application.

CHOOSING POTS AND OTHER CONTAINERS

Most pots are made from either plastic, ceramic with glazing on the outside or unglazed ceramic. Other commonly used containers include hanging baskets of wire lined with coconut fibre or synthetic material, hollow logs, rocks and water-well pots. Each has its advantages and disadvantages.

POTS

By all means choose one to suit your decor, but first check it against these notes.

- Make sure that there are enough drainage holes and that they are fully formed. Either don't buy pots with drainage holes partly blocked with slivers of plastic, or cut the slivers out before potting.
- Choose a size to suit the size of plant.
- Choose a squat pot for shallow-rooted plants, but note that the mix for shallow pots should be a little coarser than that used in deeper pots if drainage is to be good.
- Black pots withstand sunlight better than do light coloured pots. They do, however, cause the rootball to get hotter when the pots are in direct sun.
- In hot weather, evaporation of water through the sides of unglazed ceramic pots will keep the rootball cooler than is possible in impermeable pots, whether made from plastic or glazed ceramic. This evaporation will also dry the mix out more rapidly, so the mix for unglazed ceramic pots should be less open (hold more water) than the mix used in plastic pots (p. 223).

OTHER CONTAINERS

In those parts of Australia where air temperatures are likely to go over 35°C, even for one day, it is unwise to grow plants outdoors or in uncooled indoors in summer in small hanging pots made of plastic. The rootballs of plants in such pots will get so hot on hot days that the roots will be killed. The evaporative cooling provided by baskets lined with coconut fibre, Polybark (synthetic – see next page) or *Melaleuca* bark will keep roots cool enough for the plants to survive the hottest of days – as long as you keep the water up to the roots.

Very beautiful effects can be produced by growing plants in hollow logs, pots made from tree fern trunks and in hollows in mallee roots (the swollen trunk bases of the mallee eucalypts). Mallee roots make ideal anchors for *Tillandsia* – the so-called air plants (p. 237).

'Water-well' pots are ideal for plants such as African violets whose leaves are damaged by any water falling onto them (p. 237). Such pots are also ideal for busy people.

A GENERAL CAUTION

The organic parts of potting mixes gradually decompose. The air-filled porosity (its openness – see p. 223) of the remaining mix will gradually decrease. If you surround such a rootball of fine mix with a more open mix, it is possible that the old rootball will not drain into the new mix and so will remain very wet for many days in cold weather. This is a sure recipe for roots to rot.

Repotting is therefore best done in warm weather, when roots will rapidly grow into the new mix. If it has to be done in cold weather, it is essential that you roughen the surface of the old rootball so as to allow drainage of water through good contact with the new mix.

WATER AND PLANTS IN CONTAINERS

Beautiful plants in containers come with a small price tag: you must make sure that they always have an adequate supply of water. You must frequently decide whether to apply water or to hold off for a day or so longer. You know that roots can rot if you ‘overwater’, but you also know that many plants are damaged when they run out of water.

Here are the basics of watering.

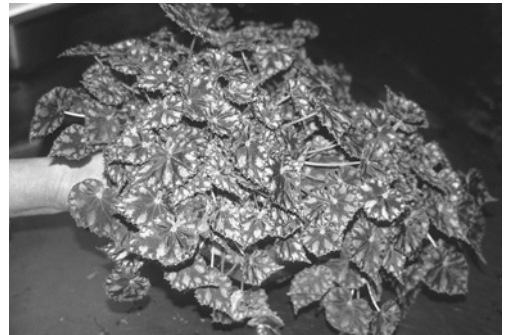
DECIDING WHEN TO WATER

For pots large and small

- Look at the surface of the mix in the pot. There is no need to water if it is obviously moist.



One way of checking for the need for water is to scratch down below the surface of the mix.



Another way is to feel the weight of a small pot.

- Investigate further if the mix looks dry or is only slightly moist. (The surfaces of some mixes can look moist yet on investigation will be found to be quite dry.) Dig down a couple of centimetres. Dry mix indicates a need to water. Moist mix probably means that you can wait another day.
- You can quickly check your diagnosis by feeling the weight of small pots.
- Another check for large pots is to tap the side of the pot. A hollow sound probably indicates a need to water.

For hanging baskets

- Wire baskets that are lined with coconut fibre, bark or synthetic materials, should be watered if the bottom of the basket feels dry.
- Test hanging (plastic) pots as given above for pots.



Water is probably not needed if the base of a basket lined with materials such as Polybark is wet to the touch.

LESS SATISFACTORY METHODS

Less satisfactory methods of deciding when to water include waiting until plants wilt, knocking the plant from the pot to see the wetness of the rootball, daily watering and using probes.

Most plants survive an occasional mild wilting, but more severe wilting reduces growth rate, can give unsightly dead leaf margins and dead shoots and can severely damage the roots of delicate plants such as maidenhair ferns.

Knocking the plant out of the pot is tedious and messy. Use this method only as an occasional check on your decision.

Daily watering may be satisfactory in summer for outdoor plants in open mixes,



One probe moisture meter reads dry and the other reads moist. Should we trust either of them?

but in cool weather and for plants in less open mixes a constantly wet mix can lead to rotting of roots.

Moisture probes are inaccurate and can be very misleading. They usually still read 'wet' when the mix is too dry for good growth of plants. The amount of fertiliser in the mix affects the reading.

Never water a wilted plant if the mix is still wet. The wilting probably means that the plants roots have been damaged. Withholding water may enable the plant to recover.

AMOUNT OF WATER TO APPLY

Having decided to water, how much should you apply? Don't ever just sprinkle a bit of water onto the surface of the mix. Rather, add enough water so that a little runs out the drainage holes. Allow for about 10% drainage if your water is saline. Excessive drainage causes excessive loss of nutrients.

The drainage water from pots indoors must be caught in a saucer. Empty this after drainage has stopped. Only where water supplies have low salinity can the water be left in the saucer for later use by the plant.

REDUCING EVAPORATION FROM THE MIX

You can increase the time between waterings by mulching the surface of the mix. Use coarse bark, such as that used for producing mixes for orchids, or any other coarse, decorative material that takes your fancy.

AVOIDING 'OVERWATERING'

Most books about pot plants warn gardeners of the perils of 'overwatering'; they terrify their readers, but rarely offer sound advice on how to avoid the problem. Once you understand what causes the problems of 'overwatering' you should find that these problems are a thing of the past.

Often the first thought gardeners have when a plant dies in a pot is that they have overwatered it. A second thought is that maybe they let it get too dry. Both thoughts might be correct, as is now explained.

Plants need water around their roots. Water is continually lost from plant tops to the air around them. This loss by transpiration must be made good with water from the potting mix.

All plant roots must also have oxygen if they are to grow and take up nutrients. A few plants – rice and the reeds are examples – supply oxygen to their roots via their leaves and stems. Most other plants have little ability to do this. Their roots must have oxygen available to them at their outer surfaces. Lack of oxygen in the potting mix is the first step towards death by overwatering.

This lack of oxygen weakens roots. Their ability to resist attack by pathogens is reduced. Wetness can stimulate some pathogens into action. The combination of active pathogens and weakened roots easily leads to invasion and root death. That in turn reduces the supply of water to the leaves. In the midst of plenty, the plant wilts and in time dies.

But what part does drought play in this? It can be important. Lack of water can damage or kill roots through dehydration or high salinity in the little water that remains in the mix. Such stressed and damaged roots are much more easily killed by pathogens than are unstressed roots. Severe drought followed by a period of ‘overwatering’ is a particularly lethal combination.

TWO CAUSES OF OVERWATERING

A mix is wettest immediately after watering. Transpiration by the plant and evaporation from the mix then gradually reduce the wetness. More air enters the mix. After some time, usually some days, you decide that the plant needs more water so you add some to the mix.

But if you water so frequently that the mix is constantly very wet, roots in the mix may not get enough oxygen. One cause of plant death by ‘overwatering’ is that you water too frequently. You suffocate the plant.

There is, however, another equally important cause – the mix itself. If it contains mainly small pores and few large ones, even when fully drained there will be little air in it. If watered frequently, such a mix will never contain much air (p. 237).

Suspect that your mix contains too little air if you often lose plants in plastic and glazed earthenware pots. You need to use a more open mix.

PREVENTING OVERWATERING

Preventing overwatering is simple: choose an 'open' potting mix.

Think of two pots, one filled with fine beach sand, the other with coarse gravel. Obviously, the spaces (pores) between particles in the sand are much smaller than those in the gravel. The gravel is more 'open' than the sand.

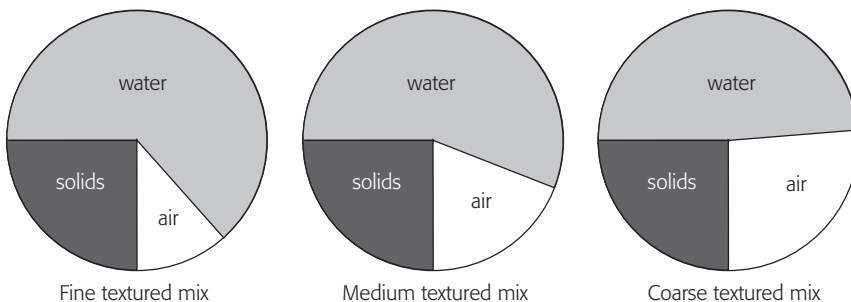
Now think of watering the two pots. After drainage has stopped, the sand will be saturated almost to the top of the pot. In fact, knocking the pot will probably cause a slurry of sand to run from the drainage holes. Few pores, if any, contain air. On the other hand, the only water held by the gravel will be a film on the surfaces of the particles and in the narrowest parts of pores where particles touch. The rest of the pores contain air.

The sand will contain too little oxygen for plant roots; the gravel will not hold enough water for any plants other than epiphytic plants such as tropical orchids.

Potting mixes must have a better balance of air and water than this.

Manufacturers give them this balance by carefully adjusting the proportions of particles of different sizes. They aim to give potting mixes for general use an air-filled porosity of 15–20%.

The air-filled porosity of a potting mix is the percentage of its volume that is air space when it has just finished draining. In other words, it is the minimum percentage of air that will be in the mix. Evaporation and transpiration steadily remove water from the mix and so steadily increase the proportion of the mix that is air.



An increasing proportion of large particles in a potting mix gives increasing proportions of air space and decreasing water content.

Desirable air-filled porosity of potting mixes different situations, as measured by the Standard Method (p. 269)

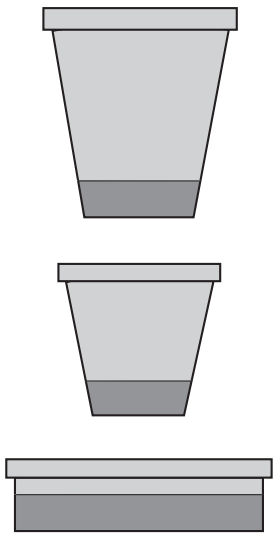
Situation	Desirable air-filled porosity (% volume)	
Seedling native plants in tubes	8–11	least open
Seed-raising mix for punnets	10–15	
Mix for larger outdoor pots	10–15	
Ferns	12–18	
General indoor plants	15–25	
Propagation mix	20–25	
Cymbidium orchids	20–30	
Epiphytic orchids	35–50	most open

All you need to measure air-filled porosity is a milk carton, bucket, sharp knife, dish and measuring jug. The method is given on p. 269. The table lists desirable ranges of air-filled porosity for different situations.

EFFECT OF POT DEPTH

Potting mix in a pot behaves in much the same way as a wet towel (one that has not been through a spin dryer) hung on a clothes line. Just after drainage has stopped, the bottom part of the towel is still saturated with water. Above the saturated part is a very wet zone, with water content then grading to the lowest level at the top of the towel. A bath towel and a hand towel of the same thickness hanging side by side on the clothes line will each be seen to have the same depth of saturated and very wet zone. But the shorter height of the hand towel will mean that its average wetness will be greater than that of the bath towel.

So it is with potting mix in pots. The depth of saturated and very wet mix is the same no matter what the total height of the mix. For the one mix, the average wetness is greater when it is in a shallow pot than when it is in a tall pot.



The height of saturated and very wet mix is the same in a container no matter what its height or width.

One effect of this is that the proportion of air in a just-drained mix will be less when it is in a shallow pot than when the same mix is in a tall pot. A potting mix in which the balance between air and water is good in a shallow seedling punnet may contain so little water in a tall pot that frequent watering of plants will be necessary. On the other hand, a mix that has excellent properties in a tall pot will probably contain too little air when placed in a squat pot.

It is therefore best to use a slightly more open mix in shallow pots than in taller pots. Also, mixes for large tubs, which are normally deep, can be quite fine. They can contain much fine sand or even 20–30% loamy soil.

Changing the width of a pot or the general shape of its sides has little effect on the proportions of air and water in potting mix in it.

CHANGING THE AIR-FILLED POROSITY OF A MIX

To increase the air-filled porosity of a mix you must add something coarser to it. The amount needed depends on the fineness of the original mix and the degree of change needed. Often the addition of about one-third by volume is a useful starting point.

The coarse material that is easiest to obtain is usually orchid mix. Other coarse materials include shredded polystyrene foam (pieces no bigger than 5 mm across – not the size of the filling of bean bags), very coarse sharp sand, 3 mm gravel (including scoria) and coarse bark.

You can reduce air-filled porosity by adding fine peat or fine sand. Start with a 10% (by volume) addition and check air-filled porosity before adding more.

When you are able to modify a mix as you wish, you can make it as open or ‘tight’ as you want. The choice is yours!

MATCHING WATERING WITH MIX, PLANT AND ENVIRONMENT

The following conditions give the greatest rate of water loss from a pot:

- low humidity;
- high air temperature;
- high mix temperature;

- bright light;
- wind;
- large plant;
- large leaves (succulents and cacti and plants with few and narrow leaves lose water much more slowly than do plants with larger leaves; variegated plants use less than all-green plants);
- an inability to stop transpiration (many thin-leaved plants from tropical lowlands seem unable to slow their rate of water loss as the growing medium dries out; they lose water until they are totally wilted; examples are *Hemigraphis* (Waffle Plant) (p. 238), *Radermachera* (China Doll), *Pentas* (Star Cluster) and *Evolvulus* (Hawaiian Blue Eyes));
- porous pot (unglazed terracotta pots and hanging wire baskets lined with porous materials lose water much more rapidly than do non-porous pots);

The table below gives an idea of the effects of indoor environment on losses of water.

The main point to be gleaned from the table is that decreasing humidity, combined with increasing draughtiness and air temperature, dramatically increases losses of water from pots.

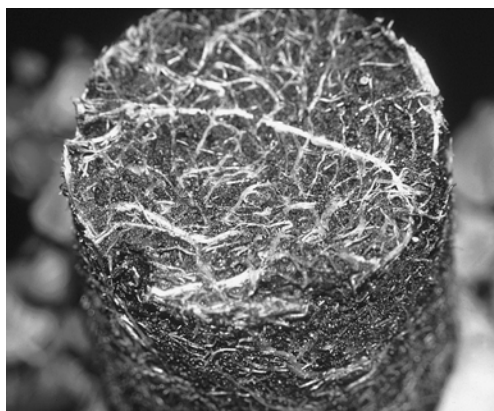
Thus, a blast of dry air from an air conditioner in winter will cause plants to lose water rapidly. A plant in a cool bathroom will have a very low rate of water loss.

For a given size of plant, watering frequency can decrease as pot size increases.

Rate of evaporation of water indoors, as affected by air temperature, air humidity and rate of air movement. The figures are mm of water evaporating per 24 hours from a dish of water				
Relative humidity of the air	Almost still air		One metre in front of a typical air conditioner	
	18°C	26°C	18°C	26°C
90% (very humid)	1	2	3	5
50%	5	10	18	33
10% (very dry)	10	19	22	48

CROCKING

Some books still state that you should place a layer of broken crockery pots (crops) or gravel in the bottom of a pot 'to improve drainage'. This may have been sensible advise when soil was the main component of pot-filling materials. But with the freely draining potting mixes now generally used and with the excellent drainage holes in plastic pots, crocking is not necessary. Commercial nurseries worldwide annually produce hundreds of millions of potted plants without crocking.



Excellent root growth shows that crocking is not necessary when open potting mixes are used.

One place where crocking is useful is in the bottoms of pots without holes. The main such 'pots' are terrariums. The spaces in the gravel act as a reservoir for any water added in excess of the holding ability of the mix. If the gravel were not there, the extra water would be retained in the mix, making it too wet. Crocking may also be desirable in terracotta pots. These typically have one relatively small drainage hole which is easily blocked.

TEMPERATURE IN POTS

The natural situation for most plants is for their roots to be in an environment of more even temperature – and during the day, lower temperature – than that around their tops. That environment is usually shaded, mulched soil.

The situation can be quite different in pots.

In the shade, the temperature of the outer part of mix in a plastic pot will be about the same as that of the surrounding air. Up to an air temperature of about 30°C the roots of most plants likely to be grown in pots will not be harmed. In fact, temperatures in the 20s give maximum growth rates for many plants.

But as mix temperature goes into the 30s, roots will be increasingly stressed. The roots of many plants are killed by several hours of temperatures over

40°C in the mix (p. 238). The roots of lettuce are damaged at 30°C. Some practical implications of this are as follows:

- Sun shining directly onto the outsides of pots will heat the mix inside. Even on a mild day (22°C) the temperature on the sunny side of black plastic pots can exceed 40°C; on a hot day, the temperature can quickly exceed 50°C. Temperatures rise highest in dark pots on light backgrounds. Always shade pots on warm-to-hot days (p. 238). This statement applies as much to pots indoors, but close to northern and western windows, as it does to pots outdoors.
- As root temperature increases, both evaporation of water from the mix and transpiration from plants increase rapidly. Watering must be more frequent.
- Evaporation of water from the sides of wire hanging baskets and unglazed terracotta pots will cool the mix inside by several degrees. This cannot happen through the sides of plastic or glazed ceramic pots. Plants tend to survive best in hot weather in baskets and unglazed pots – *as long as you water often enough to make up for the more rapid loss of water from them.*
- Many indoor plants, being from the tropics, do not like low temperatures. Daytime temperatures should be at least 15°C. Night temperatures as low as 5°C are tolerated by some species but not others. Sudden changes in temperature should be avoided: warm irrigation water to at least 15–22°C, preferably 20–25°C.
- Tropical plants being grown in cool areas will have warmer roots if they are grown in plastic pots than in terracotta pots.
- Roots can be kept cool by sinking pots into the ground. By swapping pots around from time to time you can have new landscapes to look at with little effort. This is also a useful technique when the soil of an area is totally unsuitable (e.g. too alkaline) for a particular species of plant that you want to grow.

DEALING WITH NON-WETTING MIXES

Many potting mixes are difficult to rewet if they dry out either before potting or when in pots. Suspect that mix in a pot has become non-wetting if water pours rapidly out of the drainage holes when watering. The water has run down the outside of the rootball or through the larger channels in the mix

and has hardly made it any wetter than before watering. Scratch below the surface of the mix after watering. Dryness indicates a non-wetting problem.

Difficulty in wetting is caused by the presence of waxy materials on the surfaces of particles. These waxy materials are produced mainly by fungi as they decompose organic matter.

Dry mix can be rewet by dunking the pot into a bucket of water for 10 minutes each time it dries out. This is of course a bit difficult with 30 litre tubs. Dunking is rather tedious.

WETTING AGENTS

The simplest way of ensuring quick rewetting of potting mixes is through the use of wetting agents.

A wetting agent is really just a special type of detergent that is only slowly biodegraded and that is not toxic to plants at the recommended rate of use.

The wetting agent allows water to spread more easily across the surfaces of particles in the potting mix.

A common question is: 'Why can't I use my dishwashing liquid rather than those expensive wetting agents?' The answer is that you can use a dishwashing liquid if you have nothing better. Add 2–4 mL to each litre of water used for dunking or pouring onto the dry pots.

So what's the catch? There are two. One is that the initial improvement in wettability is much less than it will be with a lower addition of a good wetting agent. The other is that the effect of dishwashing detergents disappears within



If water immediately pours from the drainage holes when watering, suspect that the potting mix has become water repellent.



Water can sit for hours on the surface of dry, water-repellent potting mix.

a week of addition, because the detergents in dishwashing liquids are required by law to be biodegradable: they are designed to be broken down in about a week by microbes in sewage treatment plants.

In contrast, the wetting agents specially formulated for use on soils and potting mixes have a low rate of degradation. When applied at the recommended rate, the best remain effective for up to eight months.

WAYS OF USING WETTING AGENTS

a. Before potting

(It is recommended that you always add wetting agent to a mix before potting – unless the bag in which it was bought states that wetting agent has already been added.)

The wetting agent should be added to the potting mix as recommended by the manufacturer. The best rate is about 0.4 mL of concentrate per litre of mix. That means that you will use about 12 mL of concentrate for a 30 litre bag of mix.

1. Dissolve the 12 mL of concentrate in 2 litres of water.
2. Spread the bag of mix out on a clean surface.
3. Sprinkle the 2 litres of dilute wetting agent over the potting mix.
4. Mix thoroughly to ensure even distribution of the wetting agent.

Alternatively, add a granular form of wetting agent (the liquid concentrate has been absorbed into solids such as attapulgite, coir or pine bark) at the recommended rate.

b. Mix already in containers, method 1

1. Make up a solution of the wetting agent by adding 1 mL of concentrate to each litre of water.
2. Dunk each pot into the solution until bubbling has stopped, indicating that the whole of the potting mix is wet.
3. Remove and allow the excess to drain back into the dunking solution.

b. Mix already in containers, method 2

1. Make up a solution of wetting agent by adding 1.5 mL concentrate to each litre of water.

2. Very slowly pour the solution all over the surface of the mix until there is some drainage from the pot.

c. Mix already in containers, method 3

1. Sprinkle granular wetting agent onto the surface of the mix, at the recommended rate.
2. Water lightly to allow release of the wetting agent from the granules.
3. Water more heavily next day to flush the wetting agent into the mix.



An effective alternative to dunking is to apply diluted wetting agent evenly over the surface of water-repellent mix in a pot.

Note: All wetting agents available in Australia will not harm plants if they are used at the recommended rate. But several of them have been found to reduce plant growth when they are applied at 2 or more times the recommended rate: do not go above the recommended strength or rate: do not apply them more frequently than once every 6 months.

AUSTRALIAN STANDARD POTTING MIXES

Potting mixes that are guaranteed to conform to the Australian Standard carry the StandardMark on their bags and a statement something like that shown in the bottom picture on p. 239.

It is recommended that you buy only those potting mixes whose packs carry this StandardMark. This Mark guarantees that the mix in the pack has been produced with properties that conform with the Australian Standard for potting mixes. That guarantee is backed by Standards Australia which, unannounced, checks the quality control records at the factory and takes random samples for independent analysis. Feedback from the analyses ensures that quality is maintained from batch to batch.

Some manufacturers have chosen not to use the StandardMark, but they do still market their potting mixes in bags that state that the contents conform with the Standard. These manufacturers conduct their own in-house testing and back the guarantee themselves, but usually without independent checking. Your plants should generally not have difficulties with these mixes.

WHAT THE STANDARD COVERS

Australian Standard AS 3743–1996 requires that a potting mix claimed to conform with it must have physical and chemical properties that ensure good plant growth.

All mixes must:

- drain well; a minimum air-filled porosity of 13% is specified for general purpose mixes;
- be easy to rewet should they dry out in the first couple of months of use;
- contain all trace elements in amounts that will be adequate for plants for one year;
- contain adequate initial amounts of the nutrients potassium, calcium, magnesium and sulphur, and in balance with one another.
- contain a level of phosphorus that is suited to the plants to be grown. Mixes for phosphorus sensitive plants have lower concentrations of phosphorus than do general-purpose mixes;
- have a suitable pH. General-purpose mixes must have a pH in the range 5.3–6.5; the pH of mixes for acid-loving plants is to be in the range 4.6–5.5.

Premium mixes must also have a supply of nitrogen sufficient to give at least one month of good plant growth even when other fertiliser is not used. In other words, you can transplant a small plant into newly bought Premium mix straight from the bag and expect the plant to grow well for at least a month before you need to apply fertiliser. The best Premium mixes will give several months of excellent growth.

The costs of testing and maintaining the high quality of these genuinely Premium mixes means that they cost more than do other mixes. You will usually find the response in your plants is well worth this extra cost.

Regular mixes are not required to have any soluble nitrogen in them when sold but the worst of the hunger of microbes in them for soluble nitrogen will have been dealt with. It is essential with them that you use a fertiliser at potting. Either include a controlled-release fertiliser in the mix before potting or use soluble fertiliser from the first watering. You will usually find that you will use less fertiliser with these Regular mixes than you need to use with cheaper, non-Standard mixes.



Heavy thatching calls for use of a scarifier, or perhaps a change in management.



This heavily used piece of lawn should be replaced with a path or stepping stones.



Coring is generally needed in home lawns only if they receive heavy use.



Just a little effort in applying fertiliser, irrigation water and herbicides would have prevented this once excellent lawn from deteriorating into a weed patch.



Begonia 'Lois Burks'.



When repotting first check that the pot to be used is neither too large nor too small for the plant.



Fill potting mix into the pot so that the top of the rootball will be about one cm below the rim of the pot.



Hold the plant like this ...



... and jerk the rootball free from the old pot.



Fill new potting mix around the old rootball ...



... and firm it down.



Don't forget to transfer the label to the new pot.



Water thoroughly.



Water-well pots are ideal for plants such as African violets whose leaves are damaged by water.



The only 'pot' a *Tillandsia* needs is a piece of bark.



This *Fuchsia* has been severely damaged through waterlogging of a poorly drained mix.



Hemigraphis plants rapidly use water until they collapse ...



...but they quickly recover after watering.



A small amount of reduced root growth on the sunny side of a pot will not harm most plants, but prolonged high temperatures will.



Roots that do not tolerate high temperatures can be protected with alfoil. 'Double potting' is a useful alternative. The pot containing the plant is placed inside a larger pot.



A red StandardMark indicates that the mix is of Premium quality.



A black StandardMark indicates that the mix is of Regular quality. These mixes are good value for money: just add controlled-release fertiliser and plant.



All bags of Standard potting mix carry information such as this. They are required to show the volume of mix in litres.



Icecream containers and casserole dishes make ideal propagation enclosures.



A light coating of vermiculite or seed raising mix keeps seeds moist and so ensures excellent germination.

Mixes for seedlings are somewhat finer than are the general-purpose mixes, those for cymbidium orchids have a higher air-filled porosity and those for bonsai have a very low air-filled porosity.

WHAT THE STANDARD DOES NOT COVER

The Standard does not cover anything that you do to the mix before you use it, nor does it compensate for poor growth that is due to poor environmental conditions around a potted plant.

All plants in all potting mixes eventually need more fertiliser than is in the potting mix when you buy it.

Over some months in pots or in the bag, even mixes that were manufactured according to the Standard may become more difficult to rewet if they get dry, no matter how excellent rewetting was when you bought the mix. That is a natural effect of continuing activity by microbes living in the mix. You will then need to improve wettability by one of the methods listed on p. 230. Soluble nitrogen in Premium mixes will slowly be used, so after months of storage you will need to add fertiliser at potting.

Standard mixes should not contain weed seeds or plant pathogens. But of course weeds will grow in them if you allow seeds to blow or be washed into them, and they can become infected with pathogens if the area around pots is dirty.

NON-STANDARD MIXES

You take pot luck with potting mixes that make no claim for compliance with the Australian Standard. Some mixes may produce satisfactory results, but spot checking has shown that they vary enormously in quality. It is impossible to tell whether the contents of a particular bag will or will not give good growth, even with the best of fertilisers. Any manufacturers who claim to have excellent products will long ago have backed these claims by testing, and will be producing according to the Standard.

Some manufacturers whose products have not been formulated according to the Australian Standard put the word 'premium' on their packs. Don't be fooled; this word is meaningless without the StandardMark as a guarantee that the mix conforms with the Premium grade of the Standard. Some of these so-called 'premium' mixes have been found to be too acid for plants and to have inadequate amounts of one or more vital plant nutrients.

LIFE IN POTTING MIXES

All potting mixes teem with microscopic life. Most of these microbes are not harmful to plants; rather, they are either neutral or beneficial. Most just quietly eat the wood, bark, coir fibre dust or peat of the mix, or one another. Some use disease-causing organisms (pathogens) as food. They are unpaid workers protecting our plants from disease. We need to look after them and help them in their important work, as follows.

MINIMISING ROOT DISEASE

Plant roots become diseased only if pathogens are present around them in sufficient numbers, the plant has little resistance of them, and the environment around the roots is favourable to the pathogens. We can do something about each of these three parts of the 'disease triangle'.

- A We can minimise the numbers of disease-causing microbes in the mix. That's where cleanliness comes in.
- B We can improve plant resistance by minimising the stress they experience.
- C We can provide a root environment which is unfavourable to pathogens.

A. *Cleanliness*

Use only Standard mixes. They will have been produced under clean conditions.

Cleanliness means all of the following for potted plants:

Wash your hands before potting/repotting if you have been working with soil.

- Use clean tools: disinfect them before use by immersing them for a few seconds in methylated spirit. Soak old pots for 5–10 minutes in bleach solution (125 mL domestic bleach of 4.5% strength diluted to 1 L or use pool chlorine) before reusing. Scrub out all old mix before disinfecting. Wear gloves when handling bleach.
- Use a clean surface for all potting operations. Swab the area with bleach



When taking cuttings, dip the secateurs into methylated spirits every several cuts.

beforehand or work on a clean plastic sheet. Keep the area free from dead foliage and unused cuttings.

- Don't allow muddy water to splash into pots.
- Don't let the ends of hoses drag along the ground before you water plants.
- Don't sit pots on bare soil or on any surface on which water can pond. Rather, use benches with tops of slats or mesh or, outdoors, stand pots on gravel. A clean, sloping concrete or asphalt surface can also be suitable, as long as water does not pond on it, or runoff from soil flow over it.
- Mix from pots in which plants have died should never be reused.

Pasteurisation with a microwave oven

Small amounts of mix for propagation by cuttings can be pasteurised in a microwave oven.

Add water to the mix so that it is moist enough to use. Fill a 4-litre ice-cream container. Place this, without a lid, in a microwave oven and zap it on full power for 7–8 minutes. Take it out and place it into a 'cooler' box for at least 30 minutes. The aim is to keep the temperature of the mix at or above 60°C for at least 30 minutes. Most pathogens are killed at this temperature. Unfortunately, most beneficial micro-organisms are also killed. Storing the moist mix for several weeks will allow a buildup of beneficial micro-organisms.



Small amounts of propagation mix can be pasteurised in a microwave oven.

B. Avoiding stress

Plants can experience stress if there is imbalance in the mix or imbalance around their tops. Imbalance in the mix can be waterlogging, drought, high salinity, poor nutrition or wrong temperature. Ways of dealing with these are discussed elsewhere. Imbalance around plant tops can be inappropriate light intensity, wrong humidity level, drought or wrong temperature. Insects and diseases which weaken plant tops will also weaken roots.

C. Making a mix less favourable to pathogens

It is likely that most mixes contain some pathogens. They will not cause problems if conditions in the mix keep their numbers low.

- Many pathogens (e.g. *Phytophthora*, *Pythium*, *Rhizoctonia*) are most active in rather wet conditions. Others (e.g. *Sclerotium*) prefer a fluctuating moisture level. Therefore, the most unfavourable condition for pathogens in a mix is even, medium water content. This is most easily achieved when the air-filled porosity of the mix is in the ideal range (see p. 224).
- Pathogens are kept in check if the mix contains large numbers of microbes which use them for food. The composted pine bark of many potting mixes usually has some suppressive activity against pathogens.
- Root-rotting diseases are less likely to be a problem in open mixes than in mixes that drain poorly. If you frequently lose plants through root rotting, you should switch to a mix with an air-filled porosity of at least 18% (p. 224).
- Fungicides can be used to suppress pathogens in potting mixes. While they can be quite effective, they cannot overcome the effects of poor physical properties of the mix. Using them on a regular basis is likely to produce a population of pathogens that is resistant to them. It is much better to start off with an open mix, to avoid overwatering and to observe strict hygiene.
- If roots do become diseased, you might be able to save the plant with quick action. Tip the plant from its pot. Carefully remove as much mix as possible by shaking and washing. Trim all dead and dying roots. Dip the remaining rootball in a fungicidal bath. Repot in new mix and treat it for a while as you would a newly transplanted seedling. That means keeping the pot in a cool place and watering only when the whole of the mix is just moist. Do not prune the plant, other than to take a cutting or two to make new plants 'just in case' your rescue effort falls.

Looking after beneficial micro-organisms

Look after the hordes of non-pathogenic microbes in your potting mix and they will do most of the work of protecting your plants for you. That means not using fungicides and fumigant chemicals. Many of them severely reduce the activity of beneficial micro-organisms such as *Trichoderma*.

PERSONAL HYGIENE

Some of the micro-organisms in soils, composts, manures and potting mixes can cause diseases in human beings. They will probably not do this if you are healthy, but it is sensible to take simple precautions when gardening.

- Wear a simple mask when handling very dusty materials or compost that sends clouds of spores into the air when it is disturbed.
- Wear gloves when handling animal manures.
- Wash your hands after gardening. Certainly do not eat until you have washed your hands.

With these simple actions, you will continue to enjoy one of the healthiest activities there is.

PROPAGATION

Gardeners often swap plants with one another. Sometimes the swapping is of cuttings or seed. Here is how to produce new plants from them.

CUTTINGS

If you have a choice, choose cuttings from a part of the parent plant well above the ground, and therefore well above possible contamination with soil. The parent should be healthy and well fed.

Take tip cuttings or, if they are too soft, take slightly hardened wood. Transport the cuttings in a plastic bag containing some damp newspaper. Deal with them as soon as you can.

You will need some propagation mix. Gardeners and nurserymen have a multitude of favourite recipes for these. Almost anything will work, just as long as the pH of the mixture is between 5.5 and 6, that the level of salts is low and that it has an air-filled porosity of about 20%. A useful mixture is 1 part coarse sand, 1 part potting mix and 1 part perlite. An open potting mix will usually work just as well as anything else.

Fill pasteurised (p. 243) propagation mix containing 1 g per litre of Nitraphoska Slow Release fertiliser or similar into 50 mm tubes or small pots.

Prepare the cuttings by removing leaves from the lower part of the stem. Halve the size of large upper leaves.

Soft cuttings will root quickly without the aid of hormones. Harder cuttings should be dipped in hormone powder or liquid.

Insert the cuttings into the mix. Do not push the lower end of the cutting below the middle of the tube. Water.

Place the tubes in an enclosure in a warm, shaded place (p. 240). Cuttings of many Australian native plants root best in bright shade. The enclosure can be a terrarium or fish tank, or can be made from a plastic bag, cut-down plastic soft drink bottle or broccoli box covered with a sheet of glass or plastic. It is essential that the cuttings remain fully moist.

Roots appear within two weeks on cuttings of some plants, but may take a couple of months for others. Even professional propagators rarely get 100% strike, so don't worry if you have some losses.

SEEDS

You need some containers, seed raising mix and an enclosure. Containers can be recycled punnets and cell packs from previous purchases of seedlings, used plastic food containers or small pots.

It is easier to buy seed raising mix than to make your own. If you make your own, you must adjust its pH into the 5–6.5 range and provide a base level of all nutrients. Nitrophoska Slow Release fertiliser or similar at 1 g per litre should do this.

Fill the mix into the containers. Gently firm the mix down. Water to fully moisten the mix. Sprinkle the seed thinly onto the surface of the mix. Cover with a very light coating of fine vermiculite, coarse sand, 3 mm gravel or seed-raising mix. Water very lightly. Place the containers in a terrarium or other container. Mist the surface of the mix from time to time as needed.

Seedlings of outdoor plants must be moved to a high-light environment as soon as they start to appear, otherwise they will elongate and they may collapse.



12 Fertilisers for plants in containers

All plants growing in containers must be fertilised from time to time (p. 273). There are many fertilisers on the market. Will they all do the same job? (No.) Which ones are best? (Read on.)

RECIPES FOR USING FERTILISERS

You can use a controlled (slow)-release fertiliser or a soluble fertiliser, or both. The amount you need to use depends on how much growth you want, or is possible at that time of the year, and is allowed by light level, and on the potting mix being used.

OUTDOOR AND GREENHOUSE PLANTS THAT YOU WANT TO GROW RAPIDLY

A. Only controlled-release fertiliser is used (p. 273)

The amounts of these fertilisers that must be used depends on the type of mix being used.

- Peat/perlite/vermiculite mix – 3 g per litre
- Australian Standard, Premium grade mix – 3–4 g per litre
- Australian Standard, Regular grade mix – 4–6 g per litre
- Other mixes – impossible to be sure, but try 5–8 g per litre; for these mixes, also add a slow-release nitrogen fertiliser such as Ezy-Green (IBDU) or Ureaformaldehyde, at 1 g per litre.

See the next table for the volume of mix in containers of various sizes.

Approximate volumes of mix held by pots of various nominal sizes			
POT SIZE		VOLUME IN LITRES (L)	
Millimetres	Inches equivalent	Standard Pot	Squat Pot
100–105	4	0.5	0.4
125–130	5	0.9	0.8
140	5.5	1.5	1.0
150	6	1.9	1.4
175	7	2.8	1.9
200	8	4.2	3.2
300	12	16	–
400	16	27	–

Example of calculation:

A patio plant in a 300 mm standard pot of Regular mix will need something like $16 \text{ (L)} \times 5 \text{ (g/L)} = 80 \text{ g}$ of a 150 day formulation.

Early growth of plants in Standard Regular mixes and ‘other’ mixes will often be improved if the first one or two waterings are with soluble fertiliser.

B. Only soluble fertiliser is used

See the table on p. 251 for examples of fertilisers that give solutions of the strength listed here. Use the higher concentrations given when rapid growth is needed, and possible. Solution volume added is to be about $\frac{1}{3}$ pot volume.

Peat/perlite/vermiculite mix – each week with a fertiliser solution containing 150–200 ppm nitrogen.

Australian Standard, Premium grade mix each week with a solution containing 200–350 ppm nitrogen.

Australian Standard, Regular grade mix – each week with a solution containing 250–400 ppm nitrogen.



A selection of the many soluble fertilisers available in garden centres and hardware stores.

Other mixes – impossible to be sure, but try feeding twice each week with a solution containing 250–400 ppm nitrogen.

C. Combination of controlled-release and liquid fertilisers is used

Use controlled-release fertiliser as listed in section A, or at slightly lower rates. Apply fertiliser solution containing 200–250 ppm nitrogen when you want to boost growth. An example is to stimulate early spring growth with a liquid feed. At that time of the year, low temperatures may not allow rapid enough release of nutrients from controlled-release fertilisers.

INDOOR PLANTS AND OTHER PLANTS THAT NEED GROW ONLY SLOWLY

Use the same types of fertilisers as listed above, but at one-quarter to one half the rate, concentration and/or frequency. For example, an indoor plant in an Australian Standard Regular mix might be given a solution containing 150–250 ppm nitrogen each 3–4 weeks, if it is to put on just a little growth.

If a large plant in a patio tub is to be maintained, with only a little extra growth being required, you would use just sufficient fertiliser to keep it from losing old leaves through starvation. You might apply controlled-release fertiliser at 2–3 g per litre of mix twice a year.



Many liquid fertilisers have both organic and soluble components.

SOLUBLE FERTILISERS

These fertilisers are either powders that dissolve rapidly and more-or-less completely in water, or liquid concentrates that are to be diluted with water. Per unit of fertiliser, the powders are cheaper than the liquids (p. 153).

If you make up 10 different soluble fertilisers according to instructions you will end up with solutions with 10 different concentrations of nutrients.

Have a look at the first column of numbers in the table on p. 251. That column lists the concentration of nitrogen that will be in the fertiliser solution when it is made up according to the instructions on the package. The bigger the number, the higher the concentration of nitrogen, and the 'stronger' the solution.

Your plants will obviously respond differently to Aquasol (368 ppm N) than to Phostrogen (47 ppm N), for example (p. 274). If you were to follow the instruction sometimes given in gardening books to apply soluble fertilisers at only quarter strength, with Phostrogen and Shultz Instant, your plants would be on a starvation diet, but on Yates Orchid they would be well fed.

You can use this table in several ways.

- Simplest way: Choose a fertiliser that gives you a solution of the strength that is suggested in Section B above.
- Slightly more complicated: Choose any fertiliser, but roughly increase or decrease the amount of solid or concentrate used so that you make a solution of the strength that you want.
- For those who want to give their plants the best: Choose the fertiliser that has the best overall content of nutrients (not only N) for your situation and calculate how much you need for the solution strength that you want. Details of how to do this are given on p. 252.



Fish emulsions make excellent fertilisers, but during and after feeding you might need to keep indoor plants outside until the fishy smell has abated.

Notes on the table opposite:

- The very large range in concentrations of nitrogen (N) in solutions made up according to recommendations.
- The equally wide ranges in phosphorus (P) and potassium (K) concentrations.
- The generally very low concentrations of sulphur (S).
- Most fertilisers do not contain calcium (Ca) or magnesium (Mg).
- Some fertilisers contain chloride (Cl). The chloride may harm plants that are sensitive to salinity, and/or increase their susceptibility to leaf diseases.
- An explanation of the P/N and K/N figures is given on pp. 257–258.
- Manufacturers sometimes change recommendations, so readers should check by calculation as shown on p. 252.

Concentration of nutrients in liquid feeds made up according to instructions*

Fertiliser	Concentration of nutrient element (ppm)							
	N	P	K	S	Ca	Mg	Cl	P/N
Campbell's Orchid B	900	132	249	–	–	–	n	0.15
Nitrosol	520	92	400	240	104	4	n	0.18
Thrive All Purpose	480	98	160	4	–	3	n	0.20
Aquasol	368	64	288	–	–	–	y	0.17
Campbell's Orchid A	354	396	498	–	–	–	n	1.12
Aquafeed	346	53	286	85	–	–	n	0.15
Harrison's Fish Emulsion	338	76	227	–	–	–	y	0.22
Garden Party	330	42	180	115	20	15	y	0.13
Thrive Flower and Fruit	300	80	520	–	–	–	n	0.27
Gardener's Choice	230	40	180	13	–	–	y	0.17
Aqua-K	219	74	360	74	–	–	n	0.33
Blossom Booster	200	264	332	–	–	–	n	1.32
Thrive Indoor	193	63	192	3	–	–	n	0.33
Miracle-Gro	187	156	154	–	–	–	n	0.83
Manutec Orchid Food	177	79	160	–	–	–	n	0.44
Maiden Hair	160	30	45	–	–	–	y	0.19
Manutec Orchid Bloom Booster	158	67	253	–	–	–	n	0.42
Garden King Fish Emulsion	147	28	42	41	3	2	n	0.19
Gro-Max African Violet Food	96	125	93	–	–	–	n	1.30
Maxicrop	92	24	62	–	–	–	n	0.26
Phostrogen Acid Plant Food	75	22	63	–	–	7.5	n	0.29
Maxicrop Indoor Plants	65	25	60	–	–	–	n	0.38
Yates Fish Emulsion	60	30	30	–	30	–	y	0.50
Shultz Instant	50	33	42	–	–	–	n	0.66
Phostrogen	50	22	113	24	20	–	n	0.44
Seasol	45	5	100	–	–	–	–	0.11

* For potted plants, or indoor plants if several instructions are given.

Legend

N = nitrogen P = phosphorus K = potassium S = sulphur Ca = calcium Mg = magnesium
Cl = chloride

CALCULATING THE STRENGTH OF A FERTILISER SOLUTION

To find what the concentration of an element will be in a fertiliser solution, you need to know its concentration in the fertiliser itself. Look on the label on the package, because by law, these labels must list the nutrient elements present and their concentrations.

The package will also carry instructions on how much to use per litre of water. Here are some examples of calculations.

For powders

Multiply the percentage of the nutrient element in the powder $\times 10 \times$ number of grams to be used per litre of solution. This gives you the concentration of the nutrient element in the solution, in parts per million (ppm).

Example: A fertiliser contains 16% N and the instruction is to dissolve 5 grams in 10 litres of water. This addition rate is $5/10 = 0.5$ g per litre.

The concentration of N in the solution will be:

$$16 \times 10 \times 0.5 = 80 \text{ ppm N.}$$

Concentrates and suspensions

Multiply the percentage (w/v) of the nutrient element in the concentrate $\times 10 \times$ number of millilitres to be used per litre of feed to obtain ppm.

Example: A fertiliser contains 3% (w/v) N and the instruction is to dissolve 50 mL in 5 L water. This addition rate is $50/5 = 10$ mL per litre

The concentration of N in the solution will be:

$$3 \times 10 \times 10 = 300 \text{ ppm N.}$$

GUARANTEED ANALYSIS.	
Nitrogen (N) as Nitrate	3.0%
Nitrogen (N) as Ammonium form	2.6%
Nitrogen (N) as Urea	21.4%
Total Nitrogen (N)	27.0%
Phosphorus (P) as Water Soluble	5.5%
Potassium (K) as Potassium Nitrate	9.0%
Magnesium (Mg) as Magnesium Sulphate	0.15%
Sulphur (S) as Sulphates	0.22%
Copper (Cu) as Copper Sulphate	0.005%
Zinc (Zn) as Zinc Sulphate	0.02%
Boron (B) as Sodium Borate	0.005%
Manganese (Mn) as Manganese Sulphate	0.04%
Iron (Fe) as Chelated Iron	0.18%
Molybdenum (Mo) as Sodium Molybdate	0.002%
Maximum Biuret	0.4%

Typical label on a pack of liquid fertiliser.

Elements essential for plant growth in a form easily absorbed by the leaves and roots of indoor plants. Use Maxicrop for Indoor Plants regularly to aid the production of healthy foliage and flowers. Directions for use: 1 Capful = 12 mL Shake container before use. Add 5 ml to 1 Litre of water. Use this solution weekly during growth period and once a fortnight during dormant periods. Apply directly to the soil or spray onto the leaves to the point of run off.	
PRODUCT ANALYSIS: %W/V	
Seaweed Extract.....	6.5
Nitrogen (N) as Urea.....	1.3
Phosphorous (P) water soluble.....	0.5
Potassium (K) as Dipotassium Hydrogen Phosphate ...	1.2
Iron (Fe).....	0.052
Copper (Cu).....	0.05
Zinc (Zn).....	0.033
Manganese (Mn).....	0.028
Boron (B).....	0.011
Molybdenum (Mo).....	0.0002
Biuret (Maximum).....	0.011
THIS PRODUCT CONTAINS 12.43% W/W TOTAL SOLIDS. 87.57% W/W ADDED WATER.	

Typical label on a pack of soluble fertiliser.

CONTROLLED (SLOW)-RELEASE FERTILISERS

The several brands of controlled-release fertilisers have one thing in common: when present in a mix or on its surface, they provide a continuous trickle of soluble nutrients over a period of some months. They therefore mimic the natural release of nutrients from minerals and humus in rich garden soils.

Convenience is the big advantage of controlled-release fertilisers. They need be applied only once every 3–6 months, compared with weekly to monthly for the soluble fertilisers. This convenience often outweighs their greater cost per unit of fertiliser.

NUTRICOTE, OSMOCOTE, GREEN JACKET, APEX AND MACRACOTE

The most commonly available controlled-release fertilisers are granules of soluble fertiliser that are coated with solidified oil (Osmocote), plastic (Nutricote, Green Jacket, Apex) or wax (Macracote). Water readily passes through the coating into the fertiliser. Nutrients are dissolved and ‘leak’ out at a rate that is determined by skin thickness and by temperature.

Controlled-release products are rated for release times such as 5 months, 9 months, 120 days and 180 days. At a constant temperature in the low 20s, most of the fertiliser will be released by the end of the specified time.

The labelling (Vegetable, Indoor, etc.) appears to be based more on marketing strategy than on scientific fact. You can use any of these formulations in any situation, except on phosphorus-sensitive native plants in soil-less potting mixes (p. 258). Most of these products are blends of formulations of different longevities, designed to give a steady supply of nutrients over the whole of the nominal release time.

It is not easy to generalise about controlled-release products, because manufacturers keep altering them. However, for all products, the rate of release increases as temperature increases. Release rate increases much more with Osmocote than with Nutricote.

Therefore, Nutricote formulations tend to be safer to use in hot weather than are Osmocote formulations of similar nominal release time.

Initially, you should use controlled-release fertilisers at the rates recommended on the packs. Once you get to know their capabilities, you may be able to reduce the amount added, or you may need to increase the rate. It all depends on how rapidly you want your plants to grow, environmental

conditions and the type of potting mix you use. It is unlikely that you will need to double the application rate. Doing so does not double the release time: it may kill your plants through high salinity.

Leaving any of the controlled-release fertilisers in open containers in constantly humid weather will allow the granules to take up moisture from the air. Some of the nutrients will escape onto the outside of the granules, so reducing their time of effectiveness once they are used.

Research has shown that, as long as you water through the top of the mix, plant growth is much the same when coated fertilisers are placed on the surface of the mix or are mixed through it.

Do not put coated fertiliser in the bottom of the pot, under the mix. Much of the fertiliser will be lost in drainage water before the plant's roots can use it. You can, however, place the fertiliser just under the old rootball when you are potting up. But for this placement you should use only long-term products.

SLOW-RELEASE FERTILISERS

Another group of fertilisers slowly provide nutrients as they break down in moist growing medium. Such products include IBDU (one brand is Gro-max Easigreen) (supplies N), Ureaformaldehyde (N) and Enmag and MagAmp (N, Mg, P, K). The various plant 'pills' and 'spikes' contain one or more of these materials. Some granular products (e.g. Nitrophoska Slow Release, Triabon) contain both a slow-release source of nitrogen and completely soluble compounds. Rates of application of these products must be lower (generally no more than 2 g/L mix) if burning is to be avoided.

Natural slow-release fertilisers include blood-and-bone (N, P, Ca), reactive rock phosphate (Ca, P) and pulverised animal manures and composts (all nutrients). They are all useful for potted plants.

HOW MUCH FERTILISER, AND HOW OFTEN TO APPLY?

You may have wondered why it was that in the recipes at the beginning of this chapter the amount of fertiliser recommended for Australian Standard Premium mixes was less than that recommended for some other mixes. This section explains why it is necessary to have these differing recommendations: they are necessary because of differences in the types of materials used to produce different potting mixes.

NITROGEN DRAWDOWN IN POTTING MIXES

The woodwastes (pinebarks, mainly, but also sawdusts and composted green organics) that are a main component of most Australian potting mixes have much carbon and little nitrogen. As they sit moist in bags and pots, they are gradually decomposed by micro-organisms similar to those present in compost heaps. Decomposition uses soluble nitrogen in the mix, in a process referred to by nursery people as 'nitrogen drawdown'.

The rate at which microbes use soluble nitrogen depends on the amount of readily useable carbon present in the woodwastes in the potting mix. Eucalypt sawdusts have a higher proportion of readily useable carbon than do pinebarks, so more fertiliser nitrogen is needed as the proportion of this type of sawdust in potting mixes increases. And as sawdust is cheaper than bark, the lowest priced (non-Standard) mixes tend to have greater proportions of sawdust than do Standard mixes. So these cheap mixes need more fertiliser than do Standard mixes if your plants are to grow well.

Nitrogen drawdown in pinebarks varies with the way the bark has been processed. Other than grinding, the bark in cheaper mixes has usually had little more treatment than being moistened and sat in a pile to age. This aging allows toxins in the bark to be decomposed by microbes, but it leaves the bark with a fairly high nitrogen drawdown rate.

In contrast, the bark used in Australian Standard mixes has been composted (p. 275). Soluble nitrogen is added to the ground bark and it is composted in windrows for 5 to 20 weeks, with frequent turning. Much of the readily useable carbon in the outer parts of bark particles has been used by microbes, so the hunger of the bark for nitrogen has been greatly reduced.

A main difference between Regular and Premium mixes is that Premium mixes will have had extra nitrogen, in both soluble and controlled-release forms, added to them just before bagging. So in a Regular mix there is some drawdown of nitrogen by microbes, but in the Premium mix, during the first few weeks of manufacture, more N is being released than is being used by microbes.

Nitrogen drawdown in peat-based mixes is slight because long ago in the swamps from which peat is mined microbes have used all of the readily useable carbon.

Other organic waste materials used in potting mixes can include peanut shells, rice hulls, coconut fibre dust, bagasse and composts made from various

urban and industrial wastes. These all have some to much ability to draw down nitrogen. For example, if coconut fibre dust is substituted for peat in a peat/perlite mix, an extra 2 g per litre of a 140 day Nutricote fertiliser must be included to compensate for use of nitrogen by the fibre. Their varying qualities and their use in varying quantities in non-Standard mixes, and the lack of quality control in factories that make these mixes, makes it impossible to know how much fertiliser needs to be added (p. 275). That is why the recommendations for non-Standard mixes at the beginning of this chapter are so vague.

INFORMATION FOR THOSE WHO WANT MORE UNDERSTANDING OF FERTILISERS

Is there a best fertiliser? No, but some fertilisers give your plants a better balance of nutrients than do other fertilisers. We have already seen that it is the concentration of nitrogen (N) that usually has the biggest effect on the growth of plants in potting mixes. Before we look more closely at the other essential nutrients, we need to consider one more aspect of the nitrogen in fertilisers.

FORM OF NITROGEN

Balance between ammonium and nitrate

Most soluble fertilisers have well over half of their N present as ammonium and urea, these being the cheapest sources of nitrogen. This means that most soluble fertilisers will tend to acidify a potting mix during repeated applications (see p. 265). The rate of drop in pH will depend on the proportion of the total nitrogen in the fertiliser that is ammonium plus urea (as opposed to nitrate), the concentration at which you use it, the frequency of use, the humus content of your potting mix and the alkalinity of your water supply.

Mixes containing much humus – from composts, composted bark, brown coal and peat – will have the slowest rate of pH change. The lime dissolved in very alkaline water may totally counteract the acidity produced by the fertiliser. Slightly alkaline waters delay acidification.

The rate of acidification of your potting mix will be greatest in those areas of Tasmania, southern Victoria and coastal New South Wales that have very pure water. Ways of counteracting or avoiding this acidification are given on p. 265.

Organic forms of N

N present in proteins and other organic compounds is only slowly available to plants. Liquid fertilisers such as the fish emulsions and blood-and-bone formulations contain part of their N in organic compounds and so they are at the same time slow-release and soluble fertilisers. The risk of burning plants through high salinity is much less with them than with completely soluble fertilisers.

PHOSPHORUS

If you analyse the leaves and flowers of plants you will usually find that the concentration of phosphorus is between 10 and 20% of that of nitrogen. Flowers usually have a lower concentration of phosphorus than do leaves.

Therefore, for excellent plant growth and flowering, the phosphorus (P) content of a fertiliser should be in the range 10–20% of its nitrogen content. Put another way, the P/N ratio of the fertiliser (P concentration divided by the nitrogen concentration) should be somewhere between 0.1 and 0.2.

Many of the fertilisers listed in the table on p. 251 do have a P content within this range, but some have a much higher proportion of P. There is no scientific evidence that supports claims that such large amounts of phosphorus ‘boost flowering’. On the contrary, large amounts of phosphorus interfere with the use of iron and other trace elements by plants, and so can decrease flowering.

The first step in encouraging excellent flowering is to provide your plants with the right environmental conditions, especially bright light (see p. 3). The next step is to provide enough nitrogen for good growth, but not lush growth. Excessive feeding with nitrogen can delay flowering; it also gives lanky growth that is prone to attack by microbes and pests.

Most plants growing in potting mixes will thrive on a fertiliser with a P/N ratio of 0.15 (p. 276). Use the same fertiliser through all seasons, but ease off on the amount used (concentration and/or frequency) with the approach of the time of the year that allows flowering.

There are three exceptions.

- Cymbidium orchids and tomatoes growing in potting mixes seem to need fertiliser with a P/N ratio of about 0.25.

- For plants sensitive to phosphorus (see pp. 261 and 276) the P/N ratio of the fertiliser should be less than 0.1, and as low as 0.05 for some.
- For potting mixes that contain some soil, the P/N ratio of the fertiliser, at least in the early months of plant growth, should be above 0.15, and perhaps as high as 0.4.

POTASSIUM

Growing trials have shown that the need of plants for potassium (K) is greater under low light conditions than under bright light. The following guidelines for potassium have been gleaned from experimental results from a range of climatic zones.

- Flowering plants in pots of soil-less potting mix in the warmer, sunnier parts of Australia and in southern Australia in mid-spring to summer, need a fertiliser with a K/N ratio (potassium concentration divided by the nitrogen concentration) of 0.8–1.2.
- Under dull winter conditions in southern Australia you could increase the K/N ratio of any fertiliser used (probably mainly for early seedlings) to about 2.
- Tomatoes will need a fertiliser with a K/N ratio of about 1.2. You can boost K supply by alternating your chosen liquid feed with a solution containing 5 g (one heaped teaspoon) potassium nitrate per 10 L.
- Foliage plants manage very nicely on fertilisers with a K/N ratio of 0.5–0.6.

If you keep up a steady program of application of fertilisers with K/N ratios as listed, you should not need to use 'blossom booster' preparations. Your plants will store luxury amounts of K in their stems and leaves during the time before flowering. If they need more K during flowering, they will shift some of this excess from the leaves to the flowers.

Excessive use of potassium can produce magnesium deficiency in plants when the water used contains little magnesium.

SULPHATE-SULPHUR, CALCIUM AND MAGNESIUM

The essential elements sulphur, calcium and magnesium are not often included in soluble fertilisers. Whether your plants do or do not eventually run short of these nutrients depends largely on their concentrations in the water you use.

Hard waters usually provide ample amounts of both calcium and magnesium; they usually contain sufficient sulphate-sulphur to balance the N your fertiliser is supplying.

Rainwater and soft waters rarely contain enough of these three elements to balance a fertiliser that lacks them. Most mixes will be able to supply these elements for some weeks to a few months, but not much longer.

You should sprinkle gypsum (calcium sulphate) at 1 g per litre or mix onto the surface of your pots every couple of months if you are using a fertiliser that contains little or no calcium and sulphate-sulphur and you are using rain water or very pure water.

Extra calcium and magnesium will probably not be needed unless the pH of the mix falls to below 5. Application of a 1:1 limestone/dolomite mixture as needed to increase mix pH (p. 267) will supply more calcium and magnesium.

Those gardeners who use rain water or whose tap water is very pure will find that long-term care of their plants is easiest if they use a fertiliser that supplies all major nutrients in balanced proportions. Use a fertiliser formulated for use in hydroponics systems, one of the several soluble fertilisers that contain all major nutrients (p. 251) or one of the 'plus' controlled-release formulations.

TRACE ELEMENTS

Potting mixes manufactured according to the Australian Standard potting have ample amounts of all trace elements for at least one year of excellent plant growth, provided the pH of the mix remains in the range 5–6.5. In fact, the iron, copper and zinc present is usually sufficient for several years. Most water supplies contain enough boron to satisfy plants in containers. If you use rain water or very pure water, you can ensure an ample supply of boron via an annual light sprinkle of seaweed mulch onto the surface of the mix. The fertilisers you use on plants in Australian Standard mixes then do not need to contain any of these trace elements. But the small amounts in most soluble fertilisers will not harm your plants.

The trace element manganese needs to be considered separately. Standard potting mixes will have enough for about 18 months of excellent plant growth. Manufacturers dare not put more in because if the mix becomes very acid (pH below 5) the manganese present can become toxic to plants. Usually you will repot a plant within 18 months of first potting, so you will have given it more manganese via the new mix used. You should use a

fertiliser that contains manganese on plants that will not be repotted for many years. If you use soluble fertiliser only, the solution should contain about 0.9 ppm manganese.

There is no guarantee that the trace element contents of non-Standard potting mixes will be adequate for your plants. The main deficiencies likely are of iron and copper (and manganese in time). With these mixes the trace elements in most soluble fertilisers might be needed, but with a mix that is severely deficient in iron, no liquid feed will be able to supply enough iron for good plant growth. These uncertainties with non-Standard mixes should encourage you to use only those mixes that conform to the Australian Standard.

AVOIDING AND OVERCOMING SALINITY PROBLEMS IN CONTAINERS

Excessive salinity – the presence of too high a concentration of salts in the water in potting mix – can be caused by the use of salty water, overuse of fertilisers, the effects of high temperature on controlled-release fertilisers and by insufficient leaching of the mix.

Here are ways of avoiding and overcoming damage to your potted plants caused by salinity.

- If your main method of watering is from below (by wick or from a capillary mat), occasionally water from above to leach out excess salts. How often ‘occasionally’ is depends on the salinity of the water used and on the evaporation rate, but it could be once a month. When the water is pure, temperature and light intensity low and humidity high, leaching might only be necessary once or twice a year.
- If your water is fairly saline (say, with an EC of 500 microSiemens/cm or higher – typical Adelaide tap water), it would be best not to water from below.
- With saline water, when watering from above, at each watering, apply enough water to allow a small amount (5–10% of that applied) to run from the drainage holes.
- Don’t allow salty water to fall onto the leaves of plants that are sensitive to salinity.

- When your water is salty, don't let the mix become too dry between waterings. Apart from the obvious effects of drought on plants, the water remaining in a dry mix can be lethal to plants because of its very high salt concentration.
- Whether your water is or is not salty, use fertilisers at rates no higher than those recommended at the beginning of this chapter. In hot weather the combination of too much controlled-release fertiliser and a rapidly drying mix can quickly give plants a lethal dose of salinity.
- Apply soluble fertilisers according to the rule 'a little, often, rather than a lot, infrequently'.

HOW TO AVOID PHOSPHORUS TOXICITY

On pp. 150–1 there are lists of some Australian native and other plants that are damaged by modest amounts of soluble phosphorus when they are being grown in sandy soils. Here that information is extended to soil-less potting mixes.

Most Australian potting mixes do not contain clay, so very little of any added phosphorus is locked away from the reach of plant roots. This means that fertilisers to be used for sensitive species in soil-less mixes can contain only modest amounts of phosphorus.

Use soluble fertilisers such as Garden Party, and Zest Pot Plant Food. The controlled-release fertilisers sold in retail packs generally contain too much phosphorus for sensitive plants. Use formulations that contain no more than 1.6% phosphorus.

In addition to low P supply, mixes for very sensitive plants such as *Grevillea* 'Robyn Gordon', *Protea* 'Pink Mink' and *Macadamia* should have a pH no higher than 5.

POTTING MIXES AND FERTILISERS FOR ORGANIC GARDENERS

If you are an organic gardener, you will probably not want to use highly soluble 'chemical' fertilisers. Therefore you must use a potting mix that has a minimal nitrogen drawdown rate (p. 277). That means that it will be based on

peat, rich, well humified compost, perlite, vermiculite, rice hulls and sand and/or soil. You will only use pinebark if it has been thoroughly humified through composting. You will avoid sawdust in any form.

To your chosen mixture you will add:

- blood-and-bone (2 g per litre) as a slow-release source of nitrogen and very slow-release source of phosphorus, and;
- pigeon manure at 1–2 g per litre (if you can be sure that the product on offer is unadulterated) or a little reactive rock phosphate (1–2 g per litre), and;
- some coir fibre dust (perhaps 20–30% of the mix volume), as a source of potassium, or;
- vermicompost (20–30%) as a source of potassium and most other nutrients, or;
- basalt or granite dust (perhaps 40 g per litre) for potassium, and;
- some gypsum (1 g per litre) for sulphate-sulphur and calcium, and;
- dolomite to increase pH to 6 or flowers of sulphur to reduce pH to 6, and;
- iron sulphate (0.5–0.75 g per litre) as a source of iron.

Other trace elements will be provided by the peat, compost, rice hulls and soil.

Here are some typical mixtures:

- peatmoss:coarse sand:perlite 6:1:1
- compost:sand or perlite:loam 2:1:1
- peatmoss:coir:sand or perlite 2:1:2
- compost:sand:peatmoss:loam 1:1:1:1
- peatmoss:perlite:vermiculite 1:1:1
- bark-based potting mix:compost:cow manure 2:1:1
- pure compost (for ferns).

SOME NOTES ON INGREDIENTS

- Wood ash is a useful source of phosphorus (about 0.6%) and potassium (about 6%) but its ability to raise pH has to be taken into account.
- Vermicompost is usually quite fine. It should make up no more than about one-third of a potting mix otherwise plant roots will not get enough oxygen.
- The proportion of compost in most of the above mixtures has been limited because it decomposes fairly rapidly. The resulting slumping means that fairly frequent repotting will be necessary.



13 Gardening in containers: some practicalities

POTTING MIX PH

HOW TO MEASURE THE PH OF POTTING MIX

Whatever method you use, obtain a sample that accurately represents the potting mix to be tested.

- Thoroughly mix the whole bag or batch of potting mix, or;
- Cut a wedge of mix from the rootball of the plant and mix it thoroughly. (p. 278).

1. Using a colorimetric test kit

- Take a sample of about half a teaspoon of mix and place it on the white mixing sheet provided.
- Proceed as shown on p. 66.

2. Using a pH meter

First, calibrate the pH meter using standard pH buffer solutions.

- Add deionised or rain water to about 60 mL of the mix until you can only just squeeze water from it.
- Take a sample of 50 mL. Use a small plastic vial or kitchen measure.
- Tip the sample into a plastic container such as that illustrated on p. 278.
- Add to it 75 mL of deionised or rain water.
- Stir, let stand for a few minutes, stir again and then;

- Insert the glass electrode of the pH meter into the slurry.
- Agitate the glass electrode in the slurry, then hold it still while you read the pH of the mix from the meter.

GENERAL GUIDELINES FOR THE PH OF POTTING MIXES

A potting mix formulated according to the Australian Standard is required to have a pH in the range 5.3 to 6.5. That is the ideal range for the vast majority of the plants you are likely to grow in it. Even ferns such as *Asplenium scolopendrium*, commonly referred to in fern-growing circles as needing alkaline or 'basic' soils and potting mixes, grows well in potting mixes of pH 6 – as long as the concentration of calcium in the mix is high enough. As pH drifts above this range, there is an increasing likelihood that plants native to acid soils will suffer from iron deficiency.

As pH drifts below 5, it is increasingly likely that plants native to neutral to alkaline soils will not be able to take up enough calcium for optimum growth. Toxicities of manganese, zinc and boron are possible as pH drifts to 4.5 and lower.

Mixes for azaleas, camellias, *Macadamia* and other acid-loving plants can range down to pH 4.5. Except for these plants, keeping mix pH in the 5.5–6 range will give best growth.

The pH of mixes not formulated according to the Australian Standard might be in the desirable range, but there is a fair chance that they will be outside it. Your author has often found mixes in retail packs with pH values below 5 (the record low is pH 3.4) and above 7. You should check the pH of any cheap mix and return it if it is not within the desirable range.

The pH of a mix can change during its time in a pot, because:

- Most fertiliser mixtures contain more of the ammonium form of nitrogen than the nitrate form. Their repeated use makes a mix more acid.
- Watering with pure 'soft' water will eventually lower mix pH.
- On the other hand, repeated use of alkaline water can increase pH, although this rise is usually balanced by the acidity produced by most fertilisers.

It is worthwhile checking the pH of mixes in a few of your pots every 3–6 months, or when growth seems poor.

Plants suffering from low pH have a rather dull lack-lustre appearance; they may wilt even when the mix is quite moist; their leaves tend to be small and sometimes have brown-black spots and dead edges; shoot tips die. The plants do not pick up when you apply more fertiliser, and indeed may look a lot worse. There will be no new white roots to be seen on the outside of the rootball. In fact, most of the roots will be brown or dead.

A plant damaged by low mix pH can be revived if it is caught in time. You can do this by removing about half of the old rootball and repotting the remainder into new mix of better pH. The remainder of the old rootball should be drenched with lime/dolomite suspension as given below. Lack of response within two months of treatment probably means that the plant has been too severely damaged.

ADJUSTING THE PH OF POTTING MIXES

Aim for an initial pH of 6 to 6.5 if you know that the mix in pots under your conditions generally becomes more acid. A pH of 5.5 may be a better starting point if the water you use is alkaline.

Make the final adjustment after you have added all the other ingredients, including soluble fertilisers and iron sulphate.

TO RAISE PH BEFORE POTTING

If the pH is lower than it should be, add a 1:1 (weight/weight) mixture of hydrated lime or agricultural limestone and dolomite, as follows.

Initial pH	Liming mixture to give pH 6 (very approximate)	
	g per litre	teaspoons (heaped) per 10 litres
4.5	2.5	5
5.0	1.5	3
5.5	1.0	2

Check the pH about one week after adding and add more if necessary.

TO LOWER PH BEFORE POTTING

- Add superfine (dusting) sulphur powder at a rate of 0.3 g per litre (one slightly heaped teaspoon per 10 L mix) for each unit of pH drop needed, or;

- Add 1 g of iron sulphate per litre of mix (1 heaped teaspoons per 5 L) to lower pH by about half a unit. Don't add more than 2 g per litre.
- You can lower pH by including some peatmoss in the mix.

TO RAISE THE PH OF MIX IN A POT

- The preferred action is to scatter on the surface of the mix a 1:1 mixture of hydrated lime and finely ground dolomite at a rate of 1–2 g per litre (one to two heaped teaspoons per 5 litres of mix) if the mix is a little above pH 5 and 2–3 g per litre if it is below 5. Water in lightly.
- An alternative method of applying liming materials is to drench the pots with a suspension of hydrated lime and dolomite (1:1). Make the suspension by stirring 5 g hydrated lime (1 heaped teaspoon) and 5 g dolomite with 1 L of water. Apply the suspension at a rate of 250 mL per 125 mm pot.



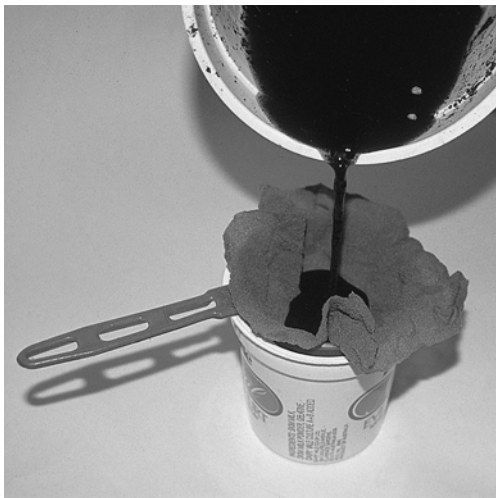
Applying lime slurry to raise the pH of potting mix in a pot.

TO LOWER THE PH OF MIX IN A POT

- Drench the mix with a solution containing 2 g per litre of iron sulphate. Use about 500 mL of solution per litre of mix (see table on p. 248). Wash any solution from plant leaves with tap water, and leach the mix within 5 minutes of drenching to prevent the plant from being damaged by high salinity.
- For a few weeks, use ammonium sulphate (0.5 g per litre = 1 heaped teaspoon per 10 litres of mix) as the only liquid feed used.
- Repeated rise in pH, despite use of acidifying fertilisers and/or iron sulphate, calls for the addition of dusting sulphur to the surface of the pot. Use no more than about 0.3 g per litre of mix (half a teaspoon per 10 litres) at any one time. Repeat after 2 months if mix pH is still too high.

MEASURING THE SALINITY OF POTTING MIX

Keen gardeners may like to buy a salinity meter for use in guiding their use of fertiliser. The cheapest salinity meters cost about \$120 (from hydroponics shops).



Filtering a potting mix slurry to give an extract whose salinity can be determined.



One of several salinity meters that cost about \$120. Choose one that has automatic temperature compensation and is waterproof.

First, calibrate the meter using a standard conductivity solution.

You can use the slurry prepared for testing pH with a meter to find the salinity of your potting mix.

- Pour the slurry through a small kitchen strainer lined with panty hose. Catch the liquid in a clean, dry glass or plastic cup.
- Dip the electrode of a salinity meter into the liquid.
- Read the digital display of the meter.

Reading	Interpretation and action
More than 2000 $\mu\text{S}/\text{cm}$ (2 dS/m)	Leach the mix to reduce its salinity.
1000–2000 $\mu\text{S}/\text{cm}$ (1–2 dS/m)	May be too high for seedlings and some plants that are intolerant of salinity.
300–1000 $\mu\text{S}/\text{cm}$ (0.3–1 dS/m)	Satisfactory.
Less than 300 $\mu\text{S}/\text{cm}$ (less than 0.3 dS/m)	Fertilise plants that are receiving only soluble fertiliser. Probably still satisfactory when controlled-release fertiliser is still actively releasing in the mix. Check when you last applied fertiliser, and how much. Add more if the time since last addition is longer than the nominal release time of the fertiliser used.

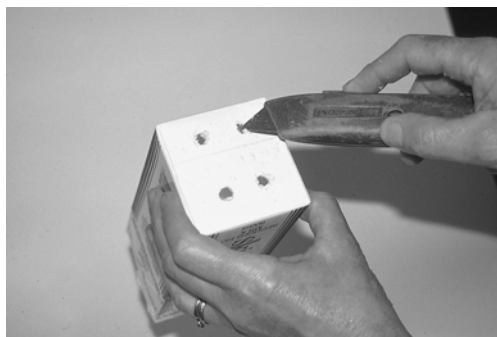
Most small meters give a reading in microSiemens per cm ($\mu\text{S}/\text{cm}$). Some give the reading in milliSiemens per cm (mS/cm) = deciSiemens per metre (dS/m). ($1 \text{ dS}/\text{m} = 1000 \mu\text{S}/\text{cm}$)

Use the table on p. 268 to interpret readings.

MEASURING THE AIR-FILLED POROSITY OF A POTTING MIX

The air-filled porosity of a mix is the percentage of its volume that is air just after it has stopped draining after being saturated with water. Measure air-filled porosity by the method below: interpretation is given on p. 224.

Note: This method may look long and complicated, but it really is very simple. Once you get the hang of it, you will take no more than 10 minutes to measure the air-filled porosity of a mix, although that 10 minutes will be spread over a couple of hours.



Drill or cut four holes in the base of a 600 mL milk carton.



Fill mix into the carton right to the top.



Drop the carton of mix five times to settle the mix.



Make sure that the water level is no higher than the height of mix.



Drain the mix.



Top up to the 600 mL mark.



Close all four holes while the carton is fully immersed. Then raise the saturated mix from its bath.



Allow water to drain from the mix.

You need the following:

- A cleaned, 600 mL milk carton.
- An electric drill or sharp knife, for making holes in the bottom of the carton,
- A 9 L plastic bucket.
- Water (warmed in winter).
- Casserole dish or 4 L icecream container.
- Two pieces of wood or plastic, each of about 1.5 cm square section and about 8 cm long.
- Measuring jug of 250 mL capacity.
- Calculator.

1. Select a cleaned, undamaged 600 mL milk carton and carefully open out the top. Mark the inside of the carton at exactly 12 cm from the base. This will usually be just above the height at which the carton had been folded over.
2. Make four holes in its base in positions such that you can close them with four fingers while holding the carton vertical with two hands. The holes should be about 8 mm diameter, or as big as your fingers will allow.
3. Fill moistened mix into the carton right to the top. Ideally, the mix should have been moist enough to use for a week or more so that all particles have had time to become wet right through.
4. Drop the carton vertically five times onto your workbench or other firm surface from a height of 5 cm. This consolidates the mix. If necessary, top up the mix to a bit above the 12 cm mark.
5. Gently lower the carton of mix into water in a 9 L bucket. The height of water should be just a few millimetres below the top of the mix. Have the water low at the start and pour more into the bucket as needed. Make sure that the mix does not float up. Leave the carton of mix in the water for 30 minutes.
6. Carefully remove the carton from the water by slowly raising it vertically. Allow to drain for a few minutes. If necessary, add extra mix to the 12 cm mark then lower the carton into the water again. Repeat once more.
7. Make a final adjustment of mix height by either adding more mix or gently scraping some out down to the 12 cm mark. Lower the carton of mix into the water and leave it for a further 10 minutes.
8. Reach down through the water and work your fingers underneath the carton until they seal the holes. Just before final sealing, make sure that the mix is saturated just to its surface.
9. Raise the carton from the water. Allow water on the outside of the carton to drip off.



Measure the volume of the drainage water.

10. Place the carton on blocks in a shallow container such as a casserole dish or 4 L icecream container. Remove your fingers. Make sure that the holes can drain freely. Allow water to drain from the carton. The base of the carton must be horizontal (any tilting or squeezing will allow more water to drain out, so giving a slightly high reading of air-filled porosity).
11. Drainage from open mixes will be complete in 10 minutes, but it could take an hour or so from very 'heavy' mixes. The water draining from the mix is replaced by air. The volume of air that enters is the same as the volume of water that has drained into the container.
12. After drainage has stopped, remove the carton from the blocks, without tilting or squeezing the container. Measure the volume of water in the shallow container, or weigh it (1 mL water weighs 1 g).
13. Calculate or measure the volume of carton occupied by the mix. (A 12 cm height of mix in a standard 600 mL milk carton will have a volume of approx. 600 mL.)
14. Calculate the air-filled porosity of the mix with the formula:

- Air-filled porosity (volume %) =

$$\frac{\text{volume of water drained (mL)}}{\text{volume of mix (mL)}} \times \frac{100}{1}$$

Example: 120 mL of water drains from 600 mL of mix

$$\text{Air-filled porosity} = \frac{120}{600} \times \frac{100}{1} = 20\%$$

That is, 20% of the volume of the mix was air immediately after it had stopped draining.

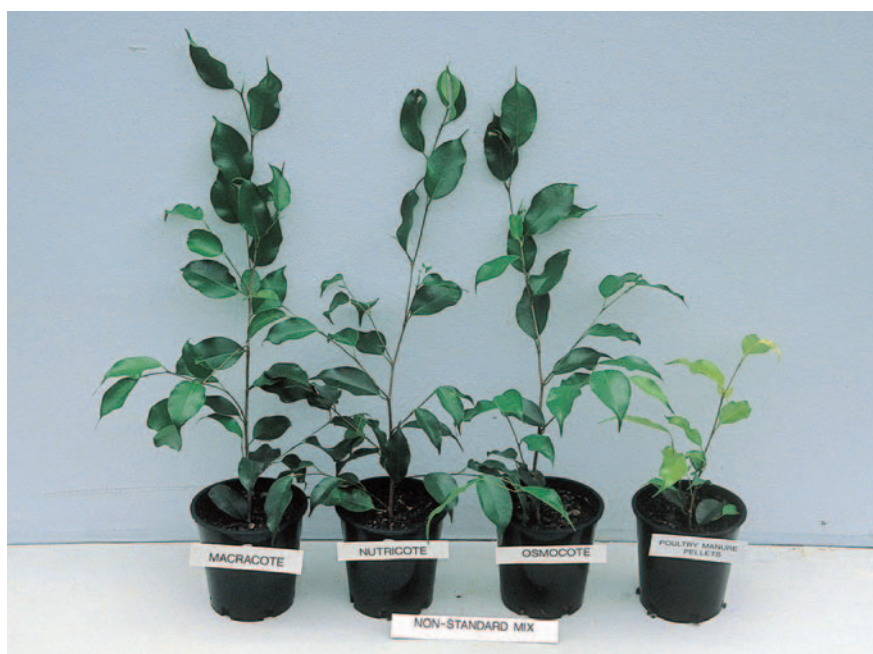
WETTABILITY OF A POTTING MIX

You can check as follows for the need to add wetting agent to a potting mix.

- Fill **dry** mix into a small dish similar to that shown on p. 279.
- Make a small depression in the centre of the mix with a standard light globe.
- Add 10 mL of deionised or rain water to the centre of the depression.



It must have been years since this poor palm had its last feed.



The several brands of coated, controlled-release fertilisers all gave excellent growth of *Ficus benjamina*. But note that in this mix, with an initial pH of 6.4, using alkaline water, this plant, which prefers a very acid mix, was slightly greener with Macracote and Osmocote than with Nutricote, because they had a higher proportion of ammonium/urea than nitrate-nitrogen. For other plants with other mixes and water qualities, the opposite result might be obtained.



346 ppm N.



219 ppm N.



Close to 100 ppm N.



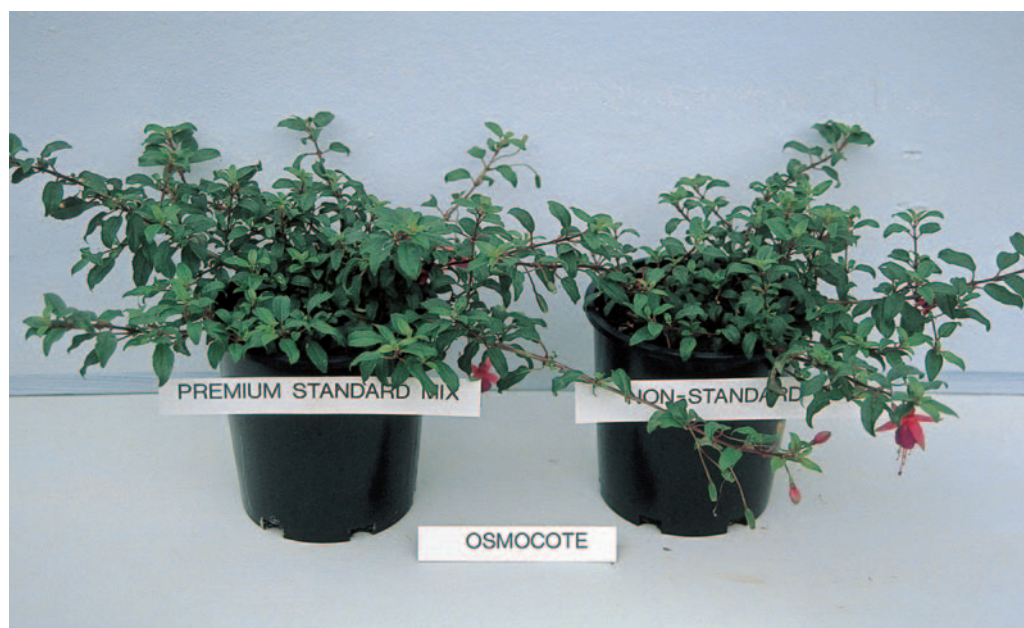
About 50 ppm N.

Examples of the effect on the growth of *Fuchsia* 'Derby Imp' of fertilisers whose solutions had a range of nitrogen concentrations. All plants were grown from cuttings of the same size from the one bush and were grown together. The fertilisers were made up and used according to recommendations on packs, which typically specified weekly additions, but sometimes at each watering. Note the poor growth in non-Standard mix at the lower levels of N application.



Debra, Tjebbs

Manufacturers repeatedly turn windrows of pine bark to ensure that the bark is thoroughly composted before it goes into a potting mix.



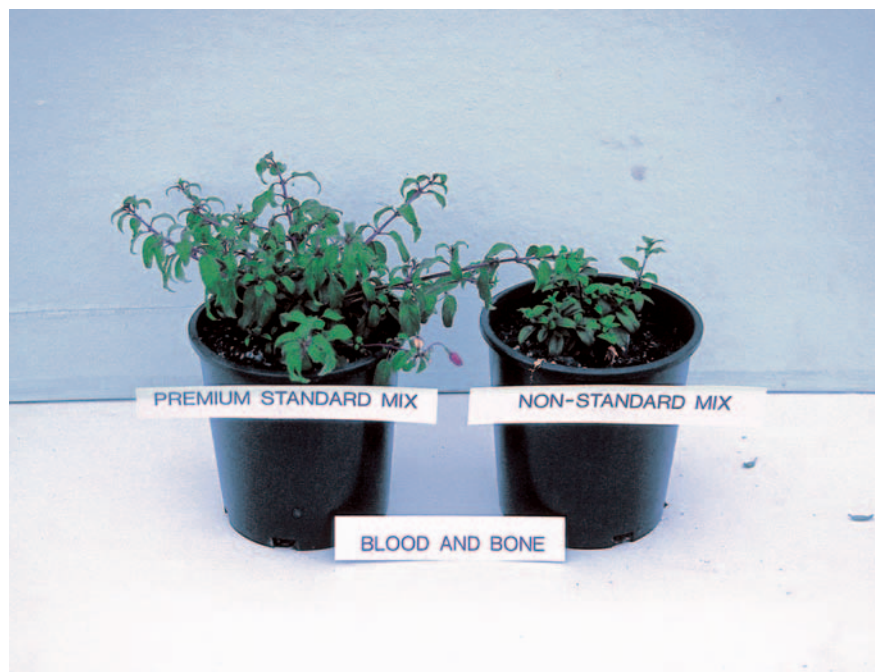
Even with a controlled-release fertiliser used at the recommended rate, growth in this non-Standard mix was inferior to that in the Standard mix.



All Australian native plants need some phosphorus, and eucalypts such as these *Eucalyptus camaldulensis* show a large response to increasing supply.



Typical symptoms of phosphorus toxicity, here in *Grevillea* 'Poorinda Firebird'.



Blood-and-bone (top) and pelleted poultry manure (bottom), added as recommended on packages, give poor growth compared with that given by high-nitrogen solutions (p. 274) and coated controlled-release fertilisers (p. 275). All plants were of the same age and had been grown together.



Measuring the pH of potting mix ... take a sample from the potted plant.



Electronic pH meters are cheap and accurate.



A watch and small plastic container are needed to measure the wettability of a potting mix. The mix will wet readily if water soaks in in less than about 30 seconds.



A few of the components that can be used to make potting mixes: composted pine bark; polystyrene foam; perlite; vermiculite.



You can achieve this too!

- Record the time for the water to soak into the mix (p. 279). The water is regarded as having soaked in when slight tilting of the dish gives no movement of water in the wet patch.
- Use wetting agent if it took longer than 30 seconds for the water to soak in.

MAKING YOUR OWN MIX

Some home-made mixes give excellent results, but your author has seen so many problems created by these mixes that he is very reluctant to offer any encouragement in this direction. But quite a few gardeners get much pleasure from experimenting and 'doing-it-themselves'. Here are some hints that can ensure a high rate of success for those who do want to try.

Unless you can get components for next to nothing, you will probably find that it is cheaper to buy potting mix formulated according to the regular grading of the Australian Standard than to buy separate components.

You must be equipped to measure the pH, salts content and air-filled porosity of each batch of mix.

You will need at least one organic component as the major ingredient and at least one mineral component.

COMPONENTS (see p. 279)

A. Organic components

Composted ground pine bark: This is probably the material of acceptable quality that is most easily found, at least in southern Australia and along the east coast to south-east Queensland. It can make up 60–90% by volume of a general mix. Detoxify raw bark by adding to it 0.75 kg iron sulphate and 1 kg ground dolomite per cubic metre (0.75 and 1 g per litre) and stacking it moist in an uncovered heap for 6 weeks. Do not add the dolomite if the bark already has a pH above 6.

Sawdust and shavings: These are inferior to pine bark because of high demand for nitrogen. Jarrah and pine sawdusts are not toxic to plant roots if used without composting, but all other hardwood sawdusts are. To compost them, add 1 kg iron sulphate, 2 kg urea and 2 kg dolomite per cubic metre. Any heap smaller than about 2 cubic metres may not heat up enough to give rapid detoxification. Composting will take at least 12 weeks. You should turn

the heap several times. High concentrations of ammonium may remain in the sawdust if composting time is shortened or you do not turn the heap.

Garden compost: This must be well matured and should be free of weed seeds.

Grape marc (composted grape skins, seeds and stalks from wineries): Use this only after it has been thoroughly decomposed. It will be very salty until leached. It contains too much potassium in relation to other nutrients. Use no more than about 20% by volume.

Mushroom composts: These are very rich in plant nutrients, so they are quite salty until leached. They are usually alkaline. Successful use is assured only if you check the pH and salinity of each batch of mix. Use no more than about 10% by volume.

Animal manures: These are useful as sources of humus and nutrients. Most contain weed seeds. Poultry manures can be quite salty so use no more than 3%, and none in mixes for native plants.

Note: The greater the combined total proportion of a mix that is readily decomposable materials such as garden compost, grape marc, mushroom compost and animal manures, the greater the rate of shrinkage of the mix. Their total proportion should not exceed about 30% by volume, with the other components being coarse sand, perlite, coarse pine bark and the like.

Rice hulls: The uniformly large size of rice hulls makes them useful for opening up an otherwise fine mix. They decompose fairly rapidly and may contain weed seeds. An upper limit to use is probably 30% by volume.

Peanut shells: These may contain nematodes and pathogens and they decompose fairly rapidly. Their properties are improved if they are aged moist in a heap or composted before use.

Peat: Different brands have different physical and chemical properties, making it difficult to generalise. The finest peats are useful for increasing the water-holding ability of bark-based mixes. Peat is useful in seed-raising mixes.

Coir fibre dust: Several brands are on the market. These materials have an excellent ability to hold water. Their fineness and high potassium content means that they should not make up more than one-third of a mix. Some batches contain chloride in concentrations that are high enough to harm

plants. Include gypsum at a rate of 1–2 g per litre of dust and iron sulphate at 0.75 g per litre. Do not use coir dust and grape marc together.

Brown coal, crushed: Including 5% in a mix will greatly increase the ability of the mix to hold nutrients. It is messy to handle.

Polystyrene foam: This synthetic organic material is useful for lightening the mix, but it blows everywhere! It has no nutritional value and does not hold nutrients.

B. Mineral components

Sand: Use a coarse grade unless you want to reduce the porosity of an open mix. The sand must not contain lime.

Soils: These contain a high proportion of fine particles. Anything more than about 15% (by volume) in a mix probably lowers air-filled porosity unacceptably. Soils also contain weed seeds and pathogens. If you use soil, use a sandy loam, use no more than about 10% and pasteurise it either by solarisation or in an oven. When everything is considered, it is recommended that soil be not used in general potting mixes, although a sandy loam can make up 60–70% by volume of mixes for large tubs.

Perlite and vermiculite: Heat-expanded rock fragments. Perlite behaves as light, water-retaining sand, but vermiculite provides some nutrients. These materials are useful in propagation mixes.

METHOD

- Start with the pinebark or the other major component. Add 10–20% by volume of the mineral component. Then add other organic components until testing shows that you have the air-filled porosity in the required range. Excellent potting mixes can be made from organic materials only, but the inclusion of mineral components can improve mix wettability and the stability of pots in windy conditions.
- Add iron sulphate to give a total of 0.75 kg per cubic metre of mix (allow for any already added to the pinebark or sawdust). Mixes that contain garden compost, vermicompost, animal manures, mushroom compost or soil should be able to supply all other trace elements. Mixes that do not contain one of these organic components should also receive 20 g copper

sulphate per cubic metre. Dissolve it in water and sprinkle the solution over the heap before thorough mixing. Add wetting agent.

- Adjust the pH into the desired range with a 1: 1 mixture of dolomite and agricultural lime if it is too acid, or dusting sulphur if it is not acid enough (see p. 267).
- If possible, check the salinity of the mix by the method on p. 267. The first watering in should be fairly heavy if the electrical conductivity of the mix is above 2 dS/m.

A FEW HINTS

Mixes containing animal manures and composts should not need any other fertiliser for a month or two of plant growth. Other mixes may benefit from an application of a mixed garden fertiliser at about 1 kg per cubic metre. Do not include poultry manure or garden fertiliser in mixes for plants that are sensitive to phosphorus. Do not add controlled-release fertilisers until just before potting. At potting, leach mixes containing coir fibre dust, unless you are sure that the dust has a low chloride content. Check the performance of your mix by comparing growth in it with growth in a Premium Standard mix.

Index

- Abelia* 147, 197
Acacia 119, 123, 126, 131, 151, 198
Acanthus mollis 197
Acid soils 55, 146, 148, 214
Acidity 54–55, 152–53
African violets 197, 218, 237
Agapanthus 197
Agave 197
Albizia 119
Alkaline soils 55, 147, 152
Alkalinity 54–55
Allocasuarina 119
Alnus 119
Alum 57–58
Aluminium 118
 toxicity 131, 148
Amazon lily 9
Ammonium 152, 282
 toxicity 126
Ammonium sulphate 56, 133, 194
Anions 53
Animal byproducts 83, 132
 see also Manures
Apple 10, 197
Apricot 197
Arbutus 197
Arctotheca 198
Arsenic 118
 toxicity 131
Asparagus 198
Asplenium scolopendrium 265
Aster 197
Atoms 50–52, 62
Australian native plants 5, 35, 150–51
 phosphorus toxicity 131, 151, 276
 water use by 171, 172
Australian Standard for Potting Mixes 231–32, 239, 241
Available water 162
Avocado 14, 147, 197
Azalea 147, 265

Baeckea 151
Bacteria *see* Micro-organisms
Banana 14, 142, 144
Banksia 146, 150, 198
Basalt dust 133, 135
Bauera 151
Bauhinia 119
Beans 141, 142, 148, 163, 197
Beaufortia 151
Bedding plants
 fertilisers for 141–48
Beetroot 143, 147, 198
Begonia 9, 197, 235
Bentgrasses 173, 201, 202
Berberis 197
Blackberry 197
Blood and bone 83, 84, 132, 134, 262, 277
Blue-green algae 118, 120, 123
Blueberry 55, 147
Bone meal 132, 134
Boron 56, 150, 259
 deficiency 130, 148
 function in plants 129
 in laundry effluents 197
 in soils 147–48
 toxicity 127, 131, 134, 148, 195
Boronia 151
Bossiaea 119, 151
Bougainvillea 198
Brachysema 151
Brassicas 125
Broccoli 143, 198
Bromeliads 175
Bromine 118, 131
Broom 197
Brown coal 283
Brownia 119
Brunfelsia pauciflora 197
Buffalo grass 200, 201, 207, 213
Buffer capacity 63–64
Bulbs
 effect of temperature 9
Bush gardens 172
Buxus 197

C/N ratio 82–83, 100
Cabbage 141, 143, 197
Cacti 4, 175, 182, 226
Calcareous soils *see* Alkaline soils
Calcium
 deficiency 56, 124, 130, 181
 from organic matter 108
 function in plants 120
 in fertilisers 150, 251, 258–59

in soils 145, 158
 toxicity 131
 Calcium sulphate *see* Gypsum
Calliandra 119
Callistemon 147, 198
Calocephalus 198
Camellia 7, 35, 146, 147, 197, 265
 Can test 168
Capsicum 143, 197
 Carbon-nitrogen ratio *see* C/N ratio
 Carnation 197
 Carpet grass 200, 201
 Carrot 141, 143, 197
Cassia 119
Casuarina 119, 122, 197, 198
 Cations 53, 62
 Cauliflower 125, 141, 147, 148
Cedrus atlantica 197
 Celery 143, 147
 Cellulose 2, 49, 50, 90
Ceratonia 119
 Chelation 108
 'Chemical' fertilisers *see* Fertilisers 'chemical'
 Chemistry 49–66
 Cherry 9
 Chloride
 effect on plants 195, 250
 in fertilisers 136, 251
 toxicity 131
Chorozema 151
Chrysanthemum 3, 7, 125, 197
 Circling roots 36–37, 46
 Citrus 14, 35, 36, 65, 76, 147, 197
 Clay 18, 19, 59–63, 104
 and pH 63–64
 as source of potassium 144
 for overcoming water repellency 113
 particles 60–61, 104
 properties 59–62
 Clay breakers 27
 Clay loam 19, 20
 Clay soils 19–20
 improving 24–25, 137, 157, 210
Clivia 197
 Cobalt 118, 130
 Coir fibre dust 282–83
 Companion plants 10
 Compost
 Australian Standard for 92
 in potting mixes 263
 iron-rich 146
 mushroom 102, 132, 282
 nutrient content 106, 108, 132
 use of 100–02, 134, 143, 282

Compost activators 80
 Compost bins 77–79
 Compost heaps 70, 78–92
 and pathogens 91–92
 carbon/nitrogen ratio 82–83
 chemical changes 90
 earthworms in 80
 micro-organisms in 84–92
 moisture content 85
 odour 86
 overcoming problems in 87
 oxygen content 86–87
 pH 56, 84, 89–90
 phosphorus 84
 temperature change 88–89, 90
 volume change 88
 Compost tea 149
 Composting 69, 77–92
 Compounds 51–53
 Containers *see* Pots
 Controlled-release fertilisers 152, 253–54, 273, 275
 Copper
 deficiency 125, 130, 150, 259, 260
 function in plants 129
 effect on earthworms 29
 in soils 147
 toxicity 56, 93, 126, 131, 148
Correa 198
Cotoneaster 197
 Couch grass 9, 200, 201, 207, 213
 Cow manure 132, 150
 Crop rotation 40
Crotalaria 119
 Cucumber 74, 143, 163, 175, 197
 Cultivation *see* Digging
 Cuttings 245–46
Cyclamen 197
Cytis 119

Dahlia 197
 Date palm 198
Daviesia 119, 151
 Detergents in laundry effluents 56, 196–97
Dichondra 147
 Digging 29–31
 double 33
 effect on organic matter 104
 Disease control 39–40, 109–111
Dodonea viscosa 198
 Dolomite 56, 84, 89, 115, 133
Dracaena 198
 Drainage 35, 39–40, 186–87
 Drought tolerance 174, 175, 201

- Dryandra* 150
- Earthworm farms 70, 93–94, 96
- Earthworms 27–29, 70, 92–99
- and vermicomposting 92–99
 - and water infiltration 156, 157, 180
 - castings 92–93, 98, 150
 - effect of copper 29
 - effect of fertilisers 29
 - effect of soil pH 29, 96
 - effect of temperature 29, 94
 - effect on soils 27–29, 71
 - enclosures 93–94
 - feeding 70, 95–96
 - in compost heaps 80
- Eelworms *see* Nematodes
- Effluent water use 196–97
- Eggplants 163
- Elaeagnus* 197
- Elements 50–53, 117–20
- Erosion 175, 185
- Erythrina* 119
- Eucalyptus* 198, 276
- Euonymus alatus* 197
- Eutaxia* 119, 151
- Evaporation 169–73, 221, 226
- Evapotranspiration 160–162, 169
- Evolvulus* 226
- Exchangeable cations 62, 63
- Feijoa* 197
- Ferns 197
- Fertiliser labels 135–36
- Fertilisers 115–36
- and earthworms 29
 - application 138, 153, 254, 275
 - ‘chemical’ 115–17, 133
 - comparison of organic and ‘chemical’ 115–17
 - composition 132–33
 - controlled-release 152, 253–54, 273, 275
 - effect on humus formation 117
 - for alkaline soils 152
 - for bedding plants 141–48
 - for fruit trees 139–40
 - for gardens 137
 - for indoor plants 249
 - for lawns 210–14
 - for potted plants 247–63
 - for shrubs 139
 - for trees 139–40
 - for vegetables 141–48
 - mineral 115–17, 133, 137–38
 - nutrient content 132–133
 - organic 115, 133, 134
 - soluble 40, 248–52, 277
 - use 137–53
- Fescues 200–02
- Ficus benjamina* 197, 273
- Field capacity 159–60
- Fig 198
- Flouride toxicity 128, 131
- Flowering 163, 257
- Flue dust 133, 135
- Foliar feeding 148–49
- Frankia* 119, 122
- Fruit 9, 10, 74
- Fruit trees
- fertilisers for 139–40
 - water use 163, 171, 189
- Fuchsia* 8, 197, 237, 274
- Fungi 7–8, 41, 90
- Fungicides 8
- Garden making 34–35
- Gardenia* 147, 197
- Gladioli 131, 197
- Gleditsia* 119
- Golden willow 197
- Granite dust 133, 135, 144
- Grape marc 282, 283
- Grapevines 131, 147, 184, 198
- Grasses 173, 200–04, 207–09
- Green manure crops 151
- Grevillea* 146, 150, 178, 261, 276
- Gypsum 115, 133
- adding to compost heaps 90
 - as source of sulphur 145
 - for lawns 203, 212
 - improving soil structure with 26–27, 137
- Gypsum test 26, 44
- Hakea* 150, 197
- Hanging baskets 220, 228
- Hardenbergia* 119
- Hay 132, 134
- Hemigraphis* 226, 238
- Hens 80
- Hibbertia* 198
- Hibiscus* 147, 198
- Holly 197
- Honeysuckle 147, 197
- Humus 59–64, 103, 105–06
- and trace element supply 109
 - as source of nitrogen 256
 - colour 14
 - formation 117
 - in soil 105–06
- Hydrangea* 58, 65, 118, 139, 147

- Hydrated lime 267
 Hydroponics 63
Hypocalymma 151
 IBDU 133, 135
Impatiens 126
Indigofera 119
 Infiltration rate of soils 156
 Ions 53, 62, 116, 192
Iresine 128
 Iron 56, 146–47, 150
 deficiency 7, 58, 65, 125, 130, 146–47, 177, 213, 260
 function in plants 129
 in foliar feeding 148
 toxicity 126, 131
 Iron chelate 146
 Iron chlorosis 109, 146
 Iron compost 146
 Iron sulphate 57, 133, 177
Isopogon 150

Jacksonia 151
 Juniper 147, 197

Kennedia 119
 Kentucky bluegrass 200–02, 207
 Kikuyu grass 200–02, 213

Laburnum 119
Lagunaria patersonii 198
Lantana 197
 Lavender 197
 Lawn clippings 75
 Lawns 199–214
 compaction of 210
 coring of 158, 233
 correcting pH 201, 210
 deficiency symptoms 213
 drought tolerance 201
 early care 206
 fertilising 147, 210–14
 for organic gardens 214
 grasses for 199–202
 ‘instant’ lawn 204–06
 mowing 201, 208–09
 planting from sprigs 204
 planting from turf 204–06
 soil preparation for 158, 202–03
 sowing 203–04
 thatch 158, 209–10, 233
 topdressing 209
 water use 171–72
 watering 206–07
Lechenaultia 151

 Legumes 108, 119, 122, 129, 141
Leptospermum laevigatum 198
 Lettuce 125, 141, 163, 197, 228
Leucadendron 151
Leucaena 119
 Light 3–4
 Lignin 2, 90
Lilac 147
Lilium 197
 Lime
 in compost heaps 90
 in soils 38, 47
 Lime-induced chlorosis 146
 Limestone 56, 57, 89, 115, 133, 135
 Linden 197
Lippia 198
 Liquid fertilisers *see* Soluble fertilisers
 Liquid manure 149–50
Liquidamber 147
 Loam soils 157
 Loams 19, 20
 Loamy sand 19, 20
Lotus 119
 Lupins 7

Macadamia 261, 265
 Magnesium
 deficiency 130, 131, 258
 from organic matter 108
 function in plants 120
 in fertilisers 150, 251, 258–59
 in lawns 213–14
 in soils 145
 toxicity 131
 Magnesium sulphate 53, 133
Magnolia 147, 197
 Major nutrients 119–20
 see also names of individual elements
 Manganese
 deficiency 125, 130, 144, 150
 function in plants 129
 in potting mixes 259–60
 in soils 147
 toxicity 56, 131, 148
 Manufactured fertilisers 133
 Manures 102, 115, 132, 134, 150, 254
 cow 102, 132, 150
 green 151
 in potting mixes 282
 nutrient content 83, 132, 150
 pigeon 84, 116, 132, 150
 poultry 84, 102, 108, 116, 132, 134, 138, 150, 277
Maranta 4

- Melaleuca* 198
 Melons 163
 Micro-organisms 7, 10, 56, 90–92, 109, 119, 122, 139, 244
 Micronutrients *see* Trace elements
Mimosa 119
 Mineral fertilisers 115, 133, 137–38
 Moisture meters 221
 Molybdenum 148, 150
 deficiency 56, 125, 130, 148
 function in plants 129
 Mowing lawns 201, 208–209
 Mulch 34, 68, 74–76, 134–35
 Mulching mowers 210, 214
 Mushroom composts 102, 132, 282
 Mycorrhizal fungi 7–8, 41
Myoporum 198
- Nandina* 147, 197
 Nematodes 40, 91
 Nitrogen 119–20, 153
 deficiency 113, 122, 130
 drawdown in potting mixes 255–56
 effect on plant growth 273
 fixation 119–120
 for lawns 213
 for vegetables 142–43
 from organic matter 102, 106–107
 in fertilisers 134–36, 142–43, 150, 152, 251, 256–57
 toxicity 131
 No-dig garden 31–34
 Non-wetting soils 113–14, 228–29
 Norfolk Island pine 198
 Nutrient solutions 63–64
 Nutrients
 absorption of 6–7
 content of fertilisers 132–33
 deficiency 130
 from organic matter 106–109
 major 117–120
 toxicity 131
 see also names of individual elements
- Oleander* 198
 Olive 198
 Onion 163, 197
 Orchids 4, 8, 128, 257
 Organic fertilisers 115–17, 132–33, 134
 see also Fertilisers
 Organic matter 100–14
 and disease control 40, 109–11
 and fertiliser needs 142
 and no-dig garden 32, 33
 and pathogens 112–13
 and soil structure 105–06, 157
 as source of nutrients 106
 benefits 104–06
 carbon content 83
 defined 103
 in potting mixes 255–56
 in soil 7, 103–14
 nitrogen content 83, 106–07, 113
 nutrient content 106–09
 phosphorus content 108
 recycling of 69, 73–93
 toxins from 112
 trace elements 108–09, 145
- Palms 124, 148
 Pansy 127
 Pathogens 39
 and organic matter 7, 109–11
 in compost heaps 91–92
 in organic matter 112–13
 in potting mixes 243–44
- Peach 10, 197
 Peanut shells 282
 Pear 197
 Peas 141, 142, 148
 Peat 58, 282
Pelargonium 198
Pentas 226
Peony 147
 Perennial ryegrass 200–02
 Perlite 256, 283
Petunia 124, 125
 pH 54–59, 65
 and potted plants 266–67
 lowering 57–58, 266–67
 measurement 58–59, 66, 264–67
 meters 59, 264–65, 278
 of compost heaps 56, 84, 89–90
 of earthworm beds 29, 96
 of nutrient solutions 64
 of potting mixes 56, 264–67, 284
 of soils 137, 158, 202, 210
 raising 56–57, 145, 152, 195, 266–67
- Philadelphus mexicanus* 122
Philodendron 197
Phlox 121
Phormium 197
 Phosphorus
 and mycorrhizal fungi 7, 8
 and proteaceous plants 131, 150–51
 availability 57–58
 deficiency 124, 130, 137–38, 153
 for lawns 203, 212–13

- for vegetables 142, 143
- from organic matter 108
- function in plants 120
- in compost heaps 84
- in fertilisers 116, 132–33, 134, 136, 150, 251, 257–58
- in potting mixes 8, 232, 258
- toxicity 126, 131, 151, 261, 276
- Photinia* 147, 197
- Photosynthesis 2–3
- Pigeon manure 84, 116, 132, 150
- Pigface 198
- Pine bark 255, 275, 281
- Pineapple 144
- Plant nutrients 117–20, 129
- Planting 35–38
- Plants
 - drought-tolerance 174, 175, 201
 - effects of drought 40, 161–62
 - effects of light 3–4
 - effects of low pH 266
 - effects of salinity 193–95, 260–61
 - effects of stress 40, 163, 181
 - effects of temperature 8–9
 - fertilising 139–49
 - nitrogen fixation 119
 - propagation 245–46
 - roots 4–7
 - tolerance to salts 197–98
 - transpiration 160–62, 226
 - water use 170–76
- Plastic film 34
- Plum 197
- Poinsettia* 197
- Polystyrene foam 283
- Potassium
 - deficiency 124, 130, 134, 138, 144, 177
 - for vegetables 143–44
 - from organic matter 108, 134
 - function in plants 120
 - in fertilisers 116, 132–33, 136, 150, 251, 258
 - toxicity 131
- Potassium chloride 133, 135, 136
- Potassium sulphate 133, 136
- Potato 143, 197
- Pots
 - crocking 227
 - depth effects 224–25
 - selection of 217–18
 - temperature in 8, 227–28
 - volumes of mix held 248
 - water loss 225–26
- Potted plants 215–46
 - and pH 266–67
 - fertilisers for 247–63
 - overwatering 221–24
 - potting mixes for 39, 232–32, 241
 - repotting 215–17, 236
 - salinity problems 260–61, 267–69
 - watering 219–224
- Potting mixes 39
 - acidification of 256
 - air-filled porosity 219, 223–25, 269–72
 - and fertilisers 247–63
 - and personal hygiene 244–45
 - and root diseases 242–44
 - Australian Standard for 231–32, 239, 241
 - components 255, 281–83
 - life in 242–44
 - making your own 262, 281–84
 - nitrogen drawdown 255–56
 - non-standard 241
 - non-wetting 228–29
 - organic 261–62
 - pasteurisation 243
 - pathogens in 243–44
 - pH 56, 264–67, 284
 - phosphorus in 8, 258
 - salinity of 267–69, 284
 - trace elements in 259–60
 - wettability 228–31, 272, 279, 281
 - wetting agents 229–31
- Poultry manure 84, 102, 108, 116, 132, 134, 138, 150, 277
- Primula* 197
- Privet* 147, 197
- Protea* 151, 261
- Proteaceous plants and phosphorus 131, 150–51
- Pultenaea* 119, 151
- Pyracantha* 147, 197
- Radermachera* 226
- Radish 197
- Raspberries 147
- Recycling 73–99
 - via burying 76–77
 - via composing 77–92
 - via mulch 74–76
 - via vermicomposting 92–99
- Repotting 215–17, 236
- Rhizobium* 56, 119, 122, 139
- Rhizosphere 6–7
- Rhododendron* 7, 56, 147, 185, 197
- Rhubarb 144
- Rice hulls 282
- Robinia* 119

- Rock phosphate 84, 115, 133, 134, 138
 Rockmelon 144, 198
 Root crops 141, 142, 147
 Root disease 39–40, 242–44
 Root hairs 6
 Rootballs 36–37, 218
 Roots 4–7, 10
 and salty water 194
 circling 36–37, 46
 effect of temperature 8–9, 238
 exudates 10
 rot 40, 219
 Roses 4, 35, 134, 139, 146, 147, 197
 Rosemary 198

 Salinity
 and plants 184, 193–95
 and potted plants 260–61, 267–69
 of potting mixes 267–69, 284
 measurement 193, 267–69
 tolerance of lawn grasses 201
 see also salty water
 Salt tolerance 197–98, 201
 Saltbush 198
 Saltwater paspalum 200, 201
 Salty water 184
 coping with 195–96
 damage to plants 193–95
 gardening with 192–98
 measurement 193
Salvia 126
 Sand
 in potting mixes 283
 Sandy clay 19
 Sandy clay loam 19
 Sandy loam 19, 20, 24
 Sandy soils 19, 20
 improving 24, 137, 138, 144, 145, 162, 214
 potassium supply in 144, 151, 177
 water repellency 113, 158
 Sawdust
 and nitrogen deficiency 113
 as mulch 75–76
 for potting mixes 281–82
 Seagrass 108, 132, 134, 135
 Seaweed 132, 135
 Seeds 2, 246
 Shrubs
 fertilisers for 139
 planting 35–38
 water use 171, 173, 189
 Silicon 118
 Silty clay loam 19, 20

 Silver beet 126
 Slow-release fertilisers *see* Controlled-release fertilisers
 Snails 32, 34
 Sodic soils 38
 Sodium 150, 194–95
 toxicity 131
 Soil aggregates 22, 23, 26, 105, 106
 Soil alkalinity 152
 Soil analysis 14–17, 38, 137, 212
 Soil blends 38
 Soil compaction 23, 157, 210
 Soil crusting 20, 21, 156
 Soil erosion 176, 185
 Soil fumigants 8, 29, 40
 Soil layers 13, 16
 Soil organic matter 103
 Soil particles 18, 22, 23
 Soil pores 25
 Soil quality 38
 Soil structure 15, 16, 21–27
 effect of organic matter 23, 74, 105–06
 improving 23–27, 31–34, 137, 157–58
 Soil texture 15–17, 18–20, 38
 and water held in soils 160, 171
 Soils
 acidification of 152–53
 available water in 162
 buffer capacity 63–64
 colour 14, 15
 components 11–12
 drainage 186–87
 effect of earthworms 27–28, 71
 field capacity 159–60
 formation 12–14
 in potting mixes 283
 infiltration of water 155–58
 non-wetting 113–114, 228–31
 odour 15
 organic matter content 103–06
 water in 154–60, 179
 water repellence 72, 113, 158
 Solarisation of soils 33, 40, 48
 Soluble fertilisers 152, 248–52, 277
 Spinach 141, 198
 Sprinklers 165–68, 176, 187–91
 Spruce 197
 Stocks 127
 Strawberries 147, 175, 197
Strelitzia 197
 Structure of soils *see* Soil structure
 Sulphur 57, 63, 116, 133, 145
 deficiency 121, 130
 function in plants 120

- in fertilisers 115, 150, 251, 258–59
- toxicity 131
- Superphosphate 84, 133, 134
- Swede 147
- Sweet corn 143, 145, 163, 197
- Sweet potato 197
- Tall fescue 200–02, 207
- Tamarindus* 119
- Tamarix* 198
- Telopea* 150
- Temperature 8–9
- Terracing 158
- Texture of soils 18–20
- Thatch in lawns 158, 209–10, 233
- Tillandsia* 218, 237
- Tomato 75, 91, 111, 124, 143, 163, 175, 181, 195, 198, 257, 258
- Topsoil 13, 14, 16, 43
- Toxicity
 - of aluminium 131, 148
 - of ammonium 126
 - of arsenic 131
 - of boron 127, 131, 134, 148, 195
 - of bromine 131
 - of calcium 131
 - of chloride 131
 - of copper 56, 93, 126, 131, 148
 - of fluoride 131
 - of iron 126, 131
 - of magnesium 56, 131, 148
 - of manganese 131
 - of nitrogen 131
 - of organic matter 112
 - of phosphorus 126, 131, 151, 261, 276
 - of potassium 131
 - of sodium 131
 - of sulphur 131
 - of zinc 56, 93, 127, 131, 148
- Trace elements 118, 129
 - and pH 56
 - from organic matter 108–09
 - in potting mixes 259–60
 - in soils 145
 - see also names of individual elements
- Transpiration 160–62, 163
- Trees
 - fertilisers for 139–40
 - planting 35–38
 - water use 171
 - watering 168, 173
- Trickle irrigation 188–89
- Tubs 39, 217
- Turnip 141, 147
- Urea 83, 133
- Urea formaldehyde 133, 135
- Urine 134
- Vanadium 118
- Vegetables 32–34, 141–48, 163, 171, 173
- Verbena* 147
- Vermicompost 93–102, 132, 262, 263
- Vermicomposting 92–99
- Vermiculite 240, 283
- Viburnum* 147, 197
- Viola* 127, 195
- Violet 197
- Waratah 150
- Water crystals 24
- Water recycling 196–97
- Water softeners 194, 196
- Watering 164–68, 173–76
 - and fungal diseases 175, 183
 - container plants 219–24
 - intervals between 166, 173
 - lawns 173, 206–07
 - systems 187–91
- Waterlogging 8, 185–87
- Weather, effect on water use 169–71
- Weathering 12–13
- Weeds
 - effect of digging 30
 - in compost heaps 79
 - seeds in vermicompost 98
- Westringia* 198
- Wettability
 - of potting mixes 228–31, 272, 279
- Wetting agents 114, 229–31
- Whiptail 125, 148
- Wisteria* 119, 147
- Wood ash 56, 133, 135
- Yucca* 198
- Zeolite 133, 214
- Zinc
 - deficiency 65, 130, 147, 150
 - function in plants 129
 - toxicity 56, 93, 127, 131, 148
- Zinnia* 197
- Zucchini* 75, 175, 183